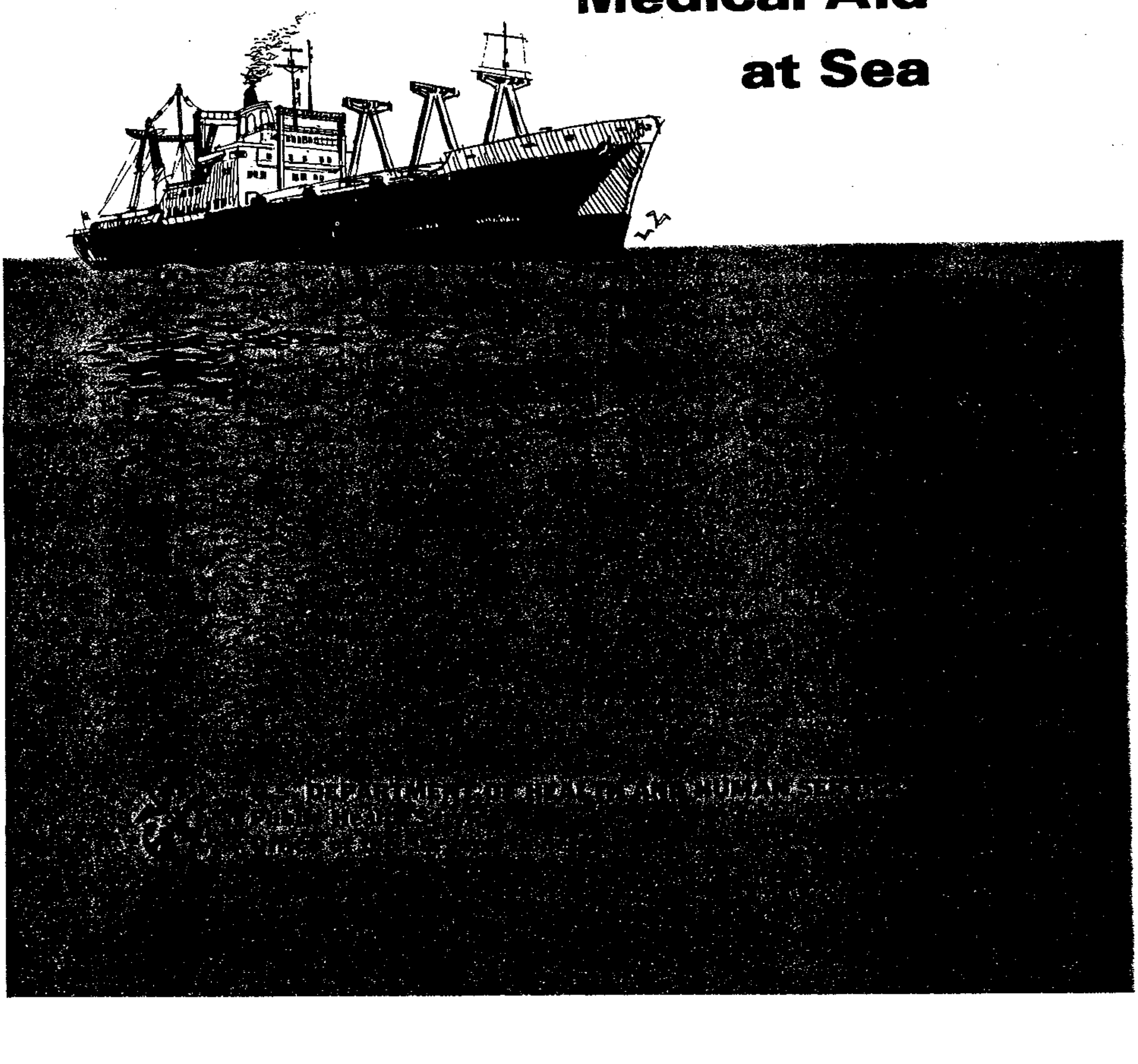
The Ship's Medicine Chest and Medical Aid at Sea



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Chapter I

Human Body

Structure and Function

TO ADMINISTER EMERGENCY TREATMENT successfully, it is essential that the person responsible for medical care at sea be able to recognize diseases and injuries. Therefore, one should have a basic knowledge of the structure of the human body as well as of the functions of its parts. A general knowledge of anatomy and physiology, similar to that given in the following pages, should help one to understand the other chapters in this book.

Anatomy is the science which deals with the structure of the body and the relationship of its parts to each other. *Physiology* is the science which deals with the *functions* of the living body and its parts. Anatomy is the science of how the machine is made (structure); physiology, the science of how it works (functions). The term *body* as used hereafter means the body as a whole, including the head, neck, trunk, and limbs *(extremities)*. The term *trunk* is limited to the chest *(thorax)* and abdomen, not including the head, neck, or limbs.

THE BODY AS A WHOLE

The human body is a complex single organism made up of several hundred trillion microscopically small cells. These basic units of life are arranged into groups that differ in size and shape to perform highly specialized tissues, organs, or organ-systems. There are muscular tissues composed of long, thin cells which have a special ability to contract and expand, permitting muscles to move the different parts of the body. There are bone cells, skin cells, and many varieties of digestive, nerve, and other kinds of cells which enable the extremely complicated human body to carry on its numerous functions.

Almost all of these different groups of cells are closely interrelated. Thus nerve cells reach into muscular tissue to stimulate the muscles into motion. Muscular motion, however, would not accomplish much were it not for the bones of the supporting skeleton and the bone cells which keep them in repair. Bone cells, together with other coordinating groups of cells, form the bone and joint *(osseo-articular)* system. Similarly, groups of different kinds of digestive cells, assembled in the mouth, stomach, liver, and elsewhere in the digestive tract contribute to different stages in the digestion of food; their different functions being closely related and their work coordinated to make up the digestive system. Other cells, tissues, and organs in the body are organized to function as the *cardiovascular, respiratory, urinary, reproductive, nervous* and *endocrine* systems. Still others form a protective *skin* for the body or make up the special sensory organs, as the *eyes* and

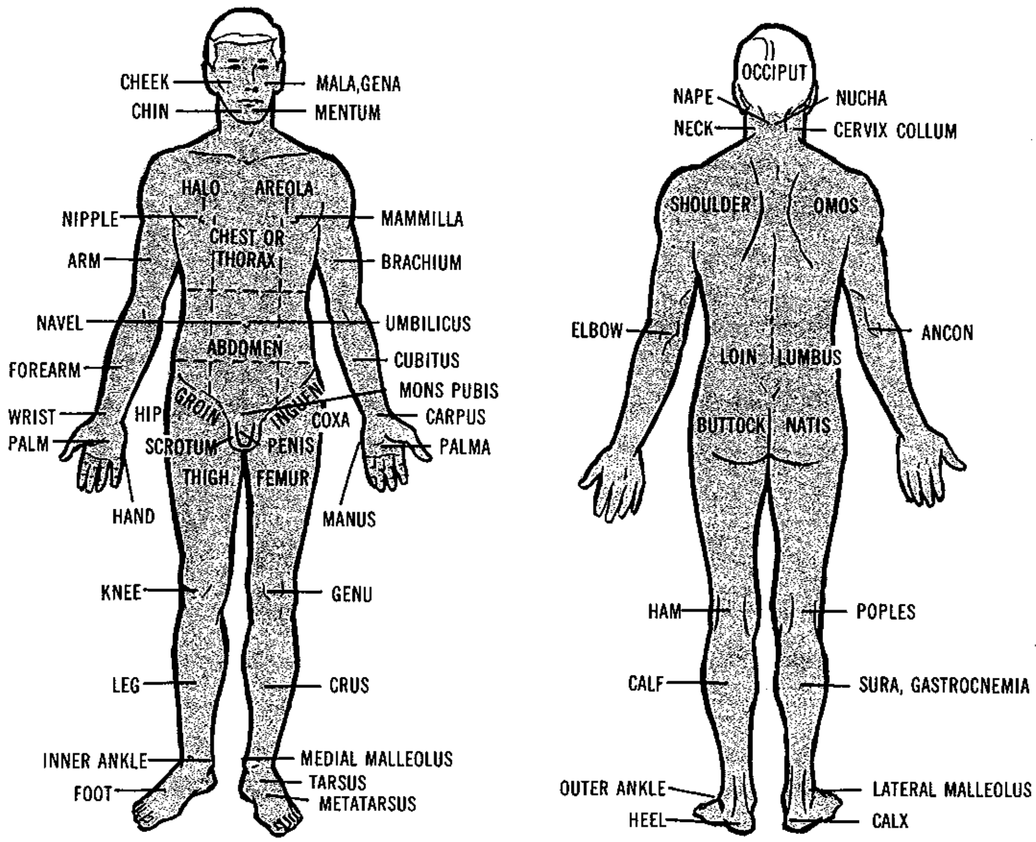

Fig. 1–1. Anatomical position and regional names of the human body. Medical terms on right side and common terms on left side.

ANATOMICAL REGIONS

In evaluating a patient's condition, it is important to know certain external and internal landmarks; that is, the anatomical regions of the body and their related parts. Reference to these landmarks makes the description of the patient's complaint or problem more understandable to others, particularly when medical advice is sought by radio. Prominent parts of the body are shown in Fig. 1–1.

THE SKIN

The human body, composed of various tissues, organs, and systems, is separated from the outside world by the skin *(integument)*, just as a ship is isolated by its hull plates from the surrounding ocean. The skin covers the whole body, protecting its deep tissues from injury, drying out, and invasion by bacteria and other foreign bodies. The skin helps to regulate body temperature, aids in the elimination of water and various salts, and acts as the receptor organ for touch, pain, heat, and cold.

The skin consists of two layers: the outer layer, the *epidermis,* and the inner layer, the *dermis* or *corium.* (See Fig. 1–2.)

The *epidermis,* which has no blood vessels or nerves, consists of four layers that from the surface inward, are: the *stratum corneum, stratum lucidum, stratum granulosum,* and *stratum germinativum.* The top layer of the epidermis, the stratum corneum, or horny layer, is made up of dead skin cells which gradually flake off or soak off when wet and are constantly renewed from cells formed in the stratum germinativum. The epidermis varies in thickness in different parts, being thickest on the palms and soles.

The corium or "true skin" is located beneath the epidermis and is composed of two layers. The upper *papillary layer* has small conelike elevations (papillae) which project into the epidermis. The papillae contain blood vessels and, in many cases, special nerve endings for the sense of touch. The deeper *reticular layer,* composed of a mesh of white fibers and elastic tissue, gives elasticity to the skin. In the tiny spaces within this mesh are the sweat *(sudoriferous)* glands and the oil *(sebaceous)* glands.

Beneath the corium and fused to it is the *subcutaneous layer* which contains many fat cells, blood vessels, and nerves. The subcutaneous layer links the corium with tissue covering the muscles and bones.

Sweat or perspiration glands occur in nearly all parts of the skin. Sweat contains essentially the same minerals as blood plasma and urine, but more diluted. Normally, only traces of the waste products excreted in urine are in sweat. But when sweating is profuse, or when the kidneys are diseased, the amounts of such wastes excreted in the sweat may be considerable. Several mineral salts are removed from the body in sweat. Chief among these in quantity is sodium chloride (common table salt).

The *four accessory structures of the skin* are the nails, hair, sweat glands, and oil *(sebaceous)* glands. (See Fig. 1–2.) The nails, the only external skeleton of the human body, are a horny, elastic material growing from a root and extending beyond the tips of the fingers and toes. Hair fibers are round, oval or flat, thin or thick, and have a root and a shaft growing from a sac *(follicle)*. Each hair is kept soft and pliable by two or more sebaceous glands which secrete varying amounts of a fatty substance *(sebum)* into the follicle near the surface of the skin. Between the hair follicles, coiled sweat glands open onto the skin's surface.

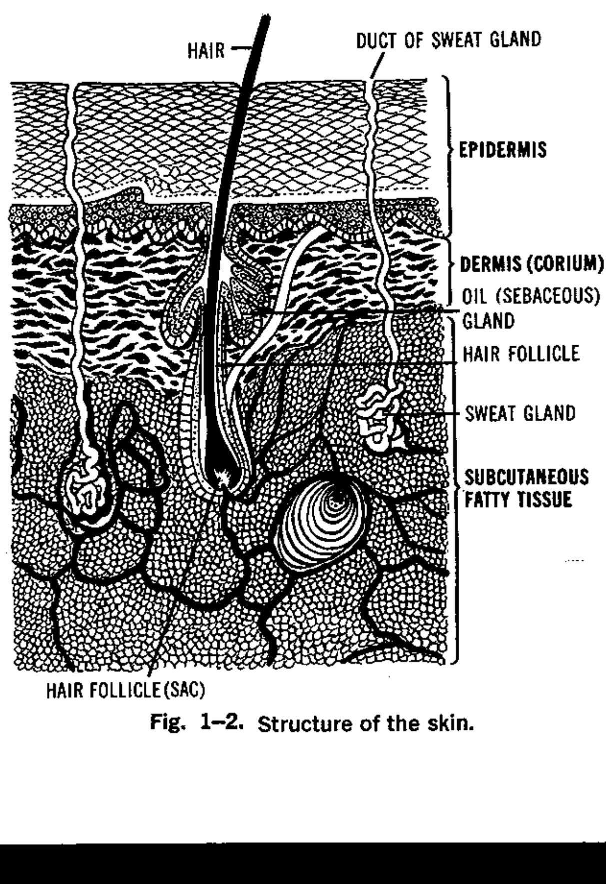

Fig. 1–2. Structure of the skin.

SKELETAL SYSTEM
(Bones and Joints)

Bones

The human body is shaped by its bony framework. Without its bones, the body would collapse.

Bone is composed of living cells and nonliving intercellular matter. The nonliving material contains calcium compounds that help to make bone hard and rigid. The body's bony framework is held together by *ligaments* which connect bone to bone; layers of *muscles; tendons* which connect muscles to bone or other structures; and various connective tissues. Bones and their adjacent tissues help to move, support, and protect the body's vital organs.

The structural framework *(skeleton)* must be strong to provide support and protection, jointed to permit motion, and flexible to withstand stress.

The skeleton in the adult has 206 bones, classified by size and shape as long, short, flat, or irregular. These may be divided into two main categories: (a) the *axial* and (b) *appendicular*. The axial skeleton consists of the bones of the head, neck, and trunk. The appendicular skeleton consists of the bones of the extremities—the arms and legs. (See Figures 1–3 and 1–4.)

Good structural design combines strength with lightness, a condition best obtained by internal bracing in a lattice arrangement. Bone has a dense, ivory-like outer shell supported by a strong inner lattice structure. Because the inner portion of the bone looks somewhat like dried sponge, it is called *spongy bone.* The crisscrossing struts of this area give support and house the *bone marrow*. Bone marrow is a

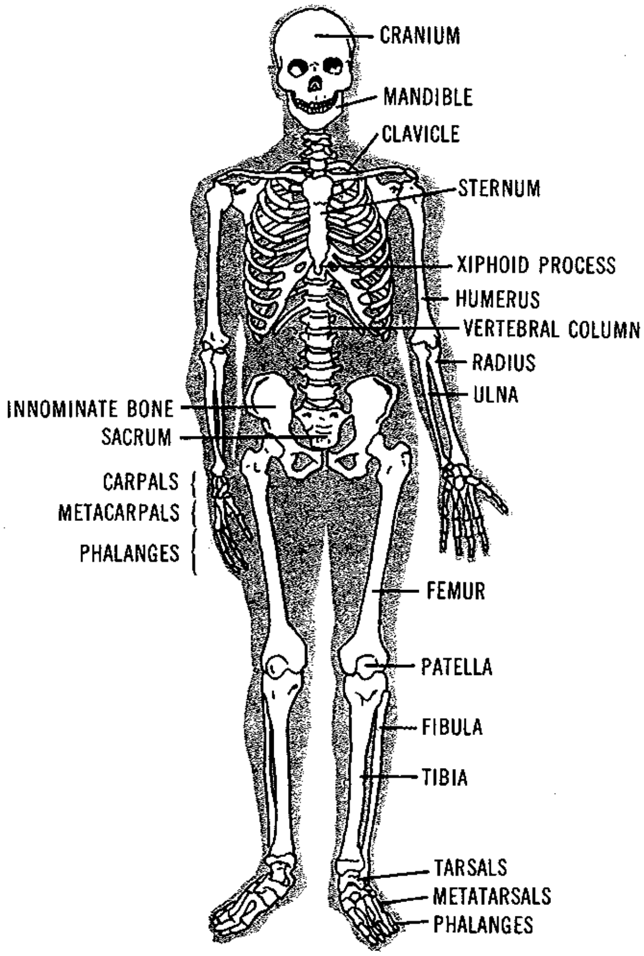

Fig. 1–3. Skeleton (front view).

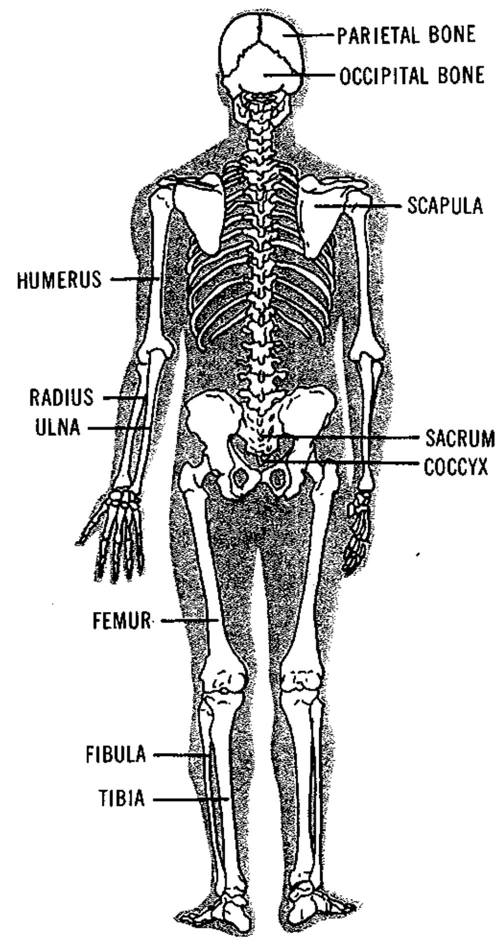

Fig. 1–4. Skeleton (back view).

principal producer of *blood cells.* Because blood cells deteriorate with use in a few weeks, an unceasing supply of new cells must be poured into the bloodstream. The *long bones* are the principal site of blood cell production.

Bone is a living tissue with numerous blood vessels and specialized bone cells *(osteoblasts)*. Broken bones are repaired by bone-building cells lying in the bone and its covering sheath, the *periosteum.* New bone is formed at the site of the break, much as two pieces of steel are welded together aboard a ship.

The shapes of bones are adapted to their function. If protection is the essential function, the bone is likely to be flat, like the shoulder blade, breastbone, and bones of the skull (*cranium*). If a bone acts principally as a lever, it usually is long, such as bones of the arms, legs, and fingers. If flexibility in a group of bones is a principal requirement, individual bones will tend to be short and irregular, as those of the wrist or ankle.

Table 1–1

THE 206 BONES OF THE SKELETON

Category	Skeleton Divisions	No. of Bones	
Axial Skeleton	Skull	28	
	Cranium (8 bones)		
	Face (14 bones)		
	Ear Bones (6 bones)		
	Hyoid Bone	1	
	Vertebral (spinal) column	26	
	Ribs and Sternum	25	
Subtotal			80
Appendicular Skeleton	Upper Extremities	64	
	Lower Extremities	62	
Subtotal			126
GRAND TOTAL			206

Joints

To allow for spatial adjustments, permit flexibility, or improve strength, the bones of the body are bound into functional units. The unit may be highly mobile (*a joint*), slightly movable *(an articulation)*, or totally immobile (*a fixed junction*). In a typical joint the layer of *cartilage* or gristle, which is softer than bone, acts as a pad or buffer. The bones of such a joint are held in place by firmly attached *ligaments*, which are the bands of very dense, tough, but flexible connective tissue.

Joints are enclosed in a capsule, a layer of thin tough material, strengthened by the ligaments. The inner side of the capsule *(synovial membrane)* secretes a thick fluid *(synovial fluid)* which lubricates and protects the joint.

Skull

The skull rests at the top of the spinal column. It contains the brain, certain special-purpose glands (such as the pituitary and pineal), and the centers of special senses—sight, hearing, taste, and smell. The brain and the spinal cord (extending downward from the brain through the spinal column) constitute the *central nervous system. Cranial nerves* originate in the brain and pass through openings in the skull, thus differing from *spinal nerves* which branch from the spinal cord. (See Fig. 1–5.)

Table 1–2

THE 8 BONES OF THE CRANIUM

Name	No.	Location
Occipital	1	Back of the head just above the nape of neck
Parietal	2	Sides and crown of head
Frontal	1	Forehead
Temporal	2	Ear region
Sphenoid	1	Base of skull to back of eye sockets (very irregular in shape)
Ethmoid	1	Base of skull to nose region (not visible without opening skull)

The skull has two parts, the brain case (*cranium*) and the *face*. The eight interlocking bones of the cranium form a firm cover for the brain. Four of these bones—the *occipital*, two *parietal*, and the *frontal*—are typical flat bones. Their outer layer is thick and tough; the inner layer is thinner and more brittle. This arrangement gives maximum strength, lightness, and elasticity.

Blood vessels and nerve trunks pass to and from the brain through openings in the

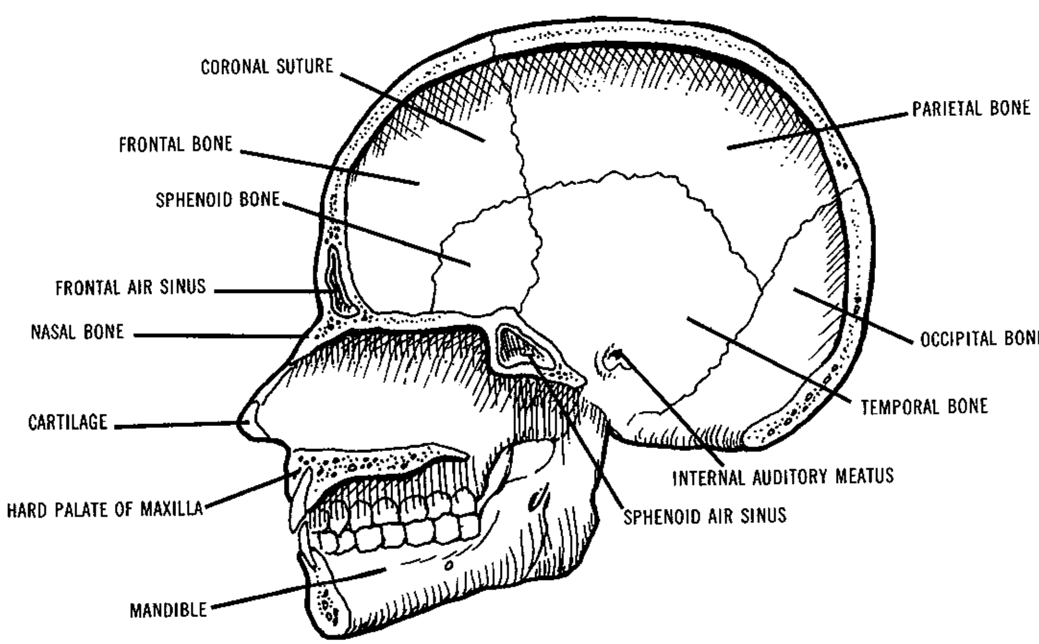

Fig. 1–5. Skull (side view).

skull, mostly at the base. The largest opening, through which the brain and spinal cord are joined, is called the *foramen magnum.*

The brain, which fits snugly into the cranium, is covered by three layers or membranes (the *meninges*). The very narrow spaces between these membranes are filled with *cerebrospinal fluid* (CSF), which is formed by a network of blood vessels in the central vesicles of the brain. It is a clear watery solution similar to blood plasma. The total quantity of CSF in the cerebrospinal system ranges from 100 to 150 ml, and the amount produced daily may range up to several liters. The CSF is constantly being produced and reabsorbed. It circulates over the surface of the brain and spinal cord, acting as a protective cushion and a means of exchange of food and waste materials. A small amount of this fluid may be removed by spinal tap *(lumbar puncture)* for study in suspected cases of brain fever *(cerebrospinal meningitis)*, syphilis of the central nervous system, and other diseases caused by infection and inflammation of the meninges.

Although the skull is very tough, a blow may fracture it. Even if there is no fracture, a sudden impact may tear or bruise the brain and cause it to swell, as any soft tissue will swell following an injury or bruise. Because the skull cannot "give," injury to the brain is magnified by the contained pressure. Unconsciousness or even death may result from swelling *(edema)*, a tearing wound *(laceration)*, bleeding, or other damage of the brain within the skull.

When recording a head injury in the ship's log, or when seeking assistance or advice by radio, the location of a visible injury should be indicated accurately by using the proper term for the area of the skull. (See Chapter XII.) Such *landmarks* as *occipital region*, right (or left) *temporal region*, right (or left) *parietal region*, or *frontal region* should be used. (See Fig. 1–5.)

Six Bones of the Ear (Ossicles)

The *temporal bones*, one on each side of the cranium, have a hollowed area with a series of small cavities. These house the *inner ear* and the *middle ear*. (See Ears, p. I–33.)

Bones of the Face

The face, extending from the eyebrows to the chin, has 14 bones, 13 of which are immovable and interlocking. The immovable bones form the bony settings of the eyes, nose, cheeks, and mouth. The fourteenth bone, the lower jaw *(mandible)*, moves freely on hinge joints.

Table 1–3

THE 14 BONES OF THE FACE

Name	No.	Location
Nasal	2	Bridge of nose (upper part)
Vomer	1	Bony part of septum (dividing wall) of nose
Inferior turbinate	2	Outer walls of nostrils (scroll-like in shape)
Lacrimal	2	Inner walls of eye sockets
Zygomatic (malar)	2	Cheeks
Palatine	2	Back part of roof of mouth
Maxilla	2	Upper jaw and front part of roof of mouth
Mandible	1	Lower jaw

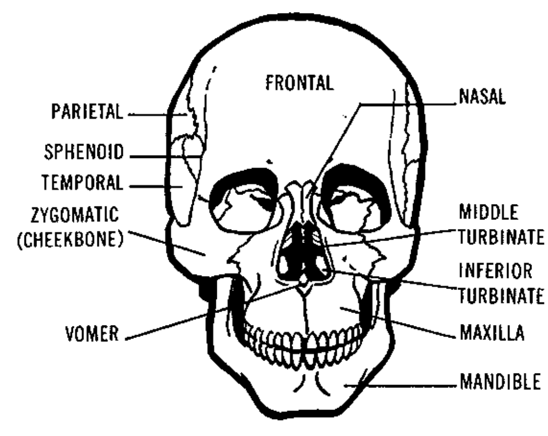

Fig. 1–6. Bones of the face and skull (front view).

Sinuses of the Head

Certain bones about the nose and inner ears contain hollows *(sinuses)*. Those about the nose are called *paranasal* or *accessory sinuses of the nose;* those about the inner ear are called *mastoid sinuses*. The paranasal sinuses communicate with the nasal passage. They are above each eye in the frontal bone

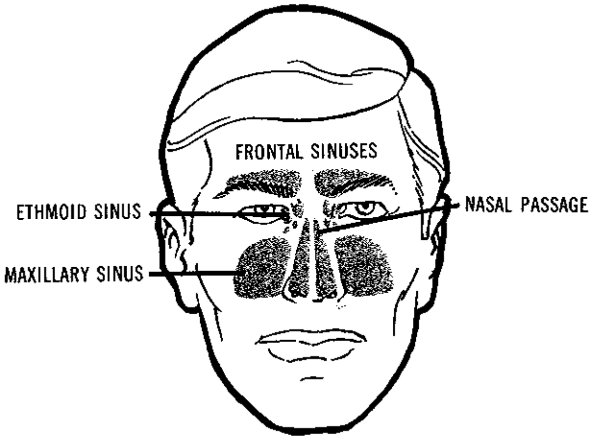

Fig. 1–7. Head showing paranasal sinuses.

(frontal sinuses), on each side of the nose in the upper jaw bones *(maxillary sinuses)*, behind the nose in the sphenoid bone *(sphenoid sinuses)*, and in the ethmoid bone *(ethmoidal sinuses)*. These spaces, which contain air, reach the nose through very narrow bony openings lined by *mucous membrane*.

When a person has a head cold, infection may travel from the nose into the sinuses. The sinus membrane becomes inflamed, swollen, and produces heavy secretions and pain over the affected sinus area in the cheeks or above the eyes. The condition is called *sinusitis*. (See Fig. 1–7.)

Eye Orbits

The eye sockets, or *orbits*, are bony cavities that house and protect the eyeballs. The eyes are further protected by the bony prominences of the cheeks, the upper part of the nose, and the heavy *supraorbital ridges* just below the eyebrows.

Nose

The *nasal bones* are two small oblong bones joined together at their inner edges to form the upper, rigid part of the bridge of the nose. The lower part of the bridge is made of cartilage. The nasal bones are easily broken on impact.

Beneath the nasal bones lies the nasal cavity, which is divided into two parts or chambers by a central wall *(septum)* of bone and cartilage. Sometimes the septum is bent, misshapen or displaced to one side, making the nasal chambers unequal in size.

Turbinates are thin, scroll-shaped bones on the outer wall of each nasal chamber. (See Fig. 1–6.) They help to increase the surface area over which air passes as it flows through the nose. Thus, they assist in warming and moistening inhaled air and freeing it of dust. Deviation of the septum following fracture, with enlargement of the turbinates, may cause interference with nasal ventilation and drainage. The reduction in air-flow due to the decreased size of the nasal passage often is seen in allergy and following trauma.

Jaws

The upper jaw is formed by two *maxillary bones* which meet in the midline of the face. Together with the *palatine bones* they form part of the palate or roof of the mouth, the floor of the eye sockets, and the floor and sides of the nasal cavities.

The lower jaw *(mandible)* is shaped like a horseshoe. It is the largest and strongest bone of the face. The curved portion forms the chin. Two perpendicular portions form hinge joints with the temporal bones located on each side of the cranium just in front of the ears. Fractures and dislocations of the lower jaw are common. (See Fig. 1–6.)

Teeth

The part of a tooth normally seen above the gum tissue (*gingiva*) is called the *crown*. The rest of the tooth (about two-thirds) below the gumline is the *root*. Front teeth have one

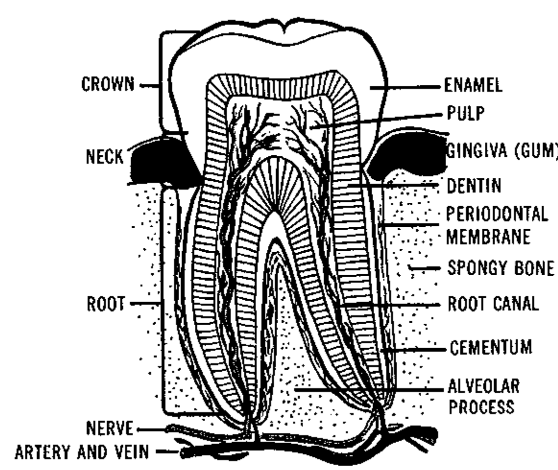

Fig. 1–8. Molar tooth and its supporting structure in the jaw.

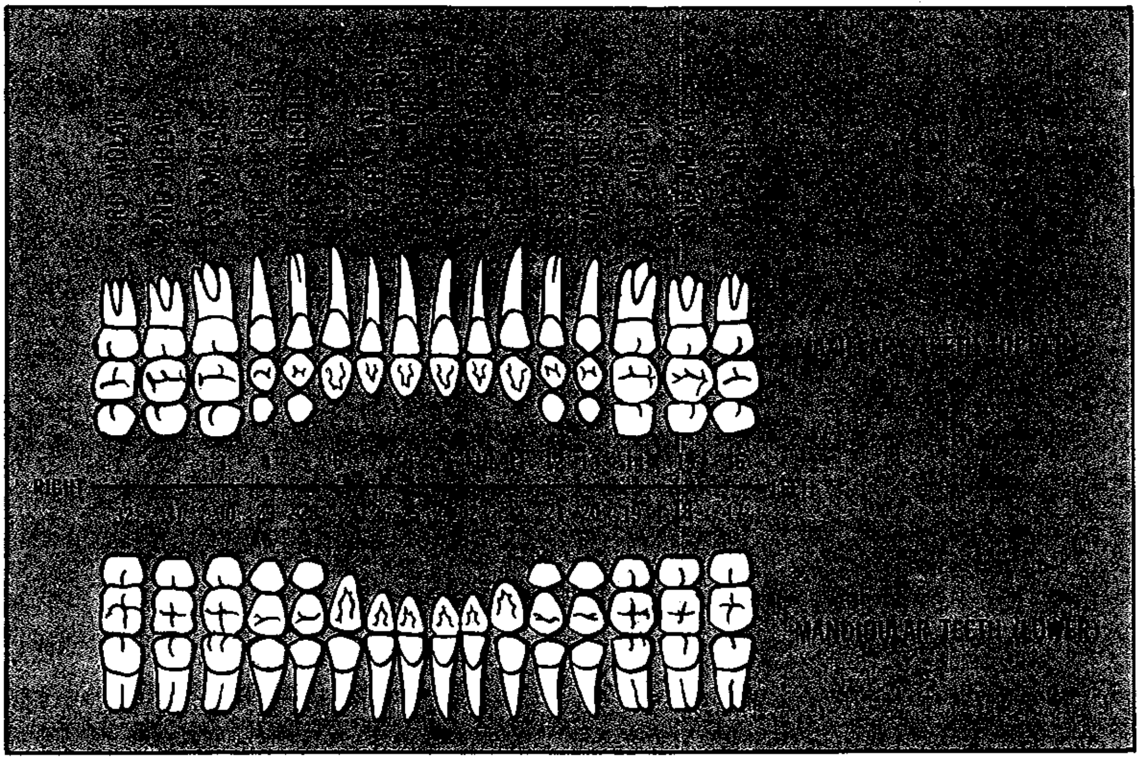

Fig. 1–9. Classification of teeth (Armed Forces System).

root while the others have two or three roots. The junction of the crown with the root is called the *neck* of the tooth. Normally the neck is at the margin of the gum tissue. (See Fig. 1–8.)

The crown is covered by a layer of *enamel,* which is the hardest substance in the human body. The root is covered with a bone-like substance called *cementum.* Beneath the covering of the enamel and cementum is the *dentin,* which is the main body of the tooth. Within the dentin is the *dental pulp,* a soft sensitive tissue composed of nerves, blood capillaries, and lymph vessels. Most of the pulp is in the crown of the tooth. The pulp in the roots extends into small canals through which the nerves and vessels pass after they enter the tooth from the jaw. The root of a healthy tooth is supported and attached to the bony socket *(alveolar bone)* in the jaw by the *periodontal membrane,* which provides both elasticity and great strength in withstanding the force required to masticate food.

Of the 32 teeth in a normal, permanent dentition, 16 are in each jaw or arch: 4 incisors, 2 cuspids, 4 bicuspids, and 6 molars. (Fig. 1–9).

In the *Armed Forces System of Classification,* the teeth are numbered from 1 to 32, beginning with the upper right third molar or wisdom tooth, and proceeding around the maxillary arch to the upper left third molar, which is No. 16. The lower left third molar is No. 17, and the numbering continues around the lower arch, ending on the lower right third molar, which is No. 32. Familiarity with the names of the teeth and the *Armed Forces System of Classification* will enable the attendant to record the site of emergency treatment.

Trunk

The trunk of the body is made up of the backbone or spine at the rear *(spinal column);* the *ribs,* which extend around the sides and meet at the breastbone *(sternum)* in front, and the heavy circular *pelvis* below. The cavity of the trunk is divided into an upper and a lower portion by a dome-shaped muscular partition *(diaphragm).* Above the diaphragm is the chest (*thorax*); below the diaphragm is the *abdomen.* The thorax contains the lower portions of the breathing apparatus (*bronchi* and *lungs*) and the *heart.* The abdomen contains the *stomach,* *intestines, liver, gallbladder, pancreas, spleen, kidneys, bladder,* and the internal organs of the *reproductive system.*

Spinal Column

The spinal column is the "principal timber" of the body. Ribs spring from it much as the ribs of a ship spring from the keel. The rest of the skeleton is directly or indirectly attached to the spine.

The spinal column has a good deal more mobility than the keel of a ship. It is made up of irregularly-shaped bones called *vertebrae* (singular-*vertebra*). Lying one on top of the other to form a strong flexible column, the vertebrae are bound firmly together by strong ligaments. Between each two vertebrae is a pad of tough elastic cartilage (the *intervertebral disc*), a shock absorber.

Table 1–4

THE 26 BONES OF THE SPINAL COLUMN

Name	No.	Location
Cervical vertebrae	7	Neck
Thoracic vertebrae	12	Thorax, or chest
Lumbar vertebrae	5	Loins
Sacrum (5 fused vertebrae)	1	Back wall of pelvis
Coccyx (4 fused vertebrae)	1	Back wall of pelvis

The vertebrae are similar in size and shape, except for the top two. Seen from above, a typical vertebra consists of a *central body,* an *arch,* and three projections, one *spinous* and two *transverse processes* or outgrowths. The spinous process extends backward and the other two extend laterally from the *arch.* Except in the fused vertebrae (*sacrum* and *coccyx*) at the base of the spinal column, all within the vertebral arch have a central opening *(vertebral foramen)* which houses the spinal cord.

The first or top vertebra is called the *atlas* because it supports the head, as in Greek mythology, the giant Atlas was thought to have supported the universe on his back. Unlike the other vertebrae, the atlas has no body, only an

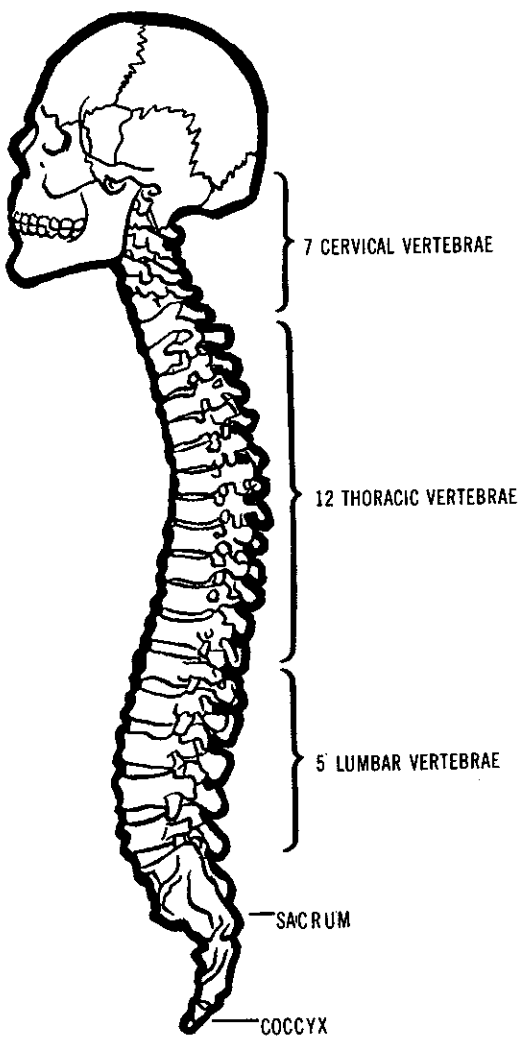

Fig. 1–10a. The spinal column.

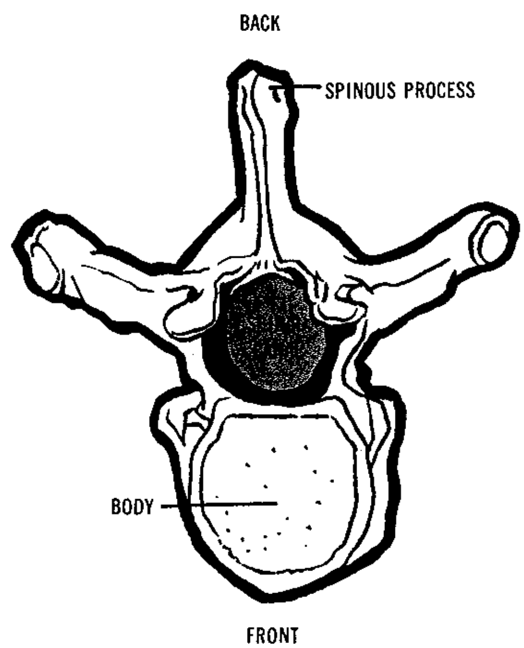

Fig. 1–10b. A typical vertebra.

arch or bony ring. There are cups on the top surface into which knobs of the occipital bone of the skull fit, making possible the backward and forward movements of the head. A bony projection rising from the second neck vertebra (the *axis*) forms a pivot around which the atlas rotates when the head is turned from side to side.

In general, the spinal column viewed from the side looks like a string of spools with winglike projections behind. The spinal column is shaped (curved) and flexible in order to carry body weight, absorb shocks, and make possible the bending of the body forward, backward, and sideways. The spinal column protects the vital spinal cord and still permits relatively free movement of the spine.

The spinal column may be damaged by disease or by injury. If any of the vertebrae are crushed or displaced, the spinal cord at that point may be squeezed, stretched, torn, or severed. Movement of the disabled part by the injured person, or careless handling by well-meaning but uninformed persons, may result in displacement of sections of the spinal column, causing further injury to the cord and possibly resulting in permanent paralysis. For this reason, a person with a back or neck injury must be handled with extreme care.

Breastbone (Sternum) and Ribs

The *sternum* is a flat, narrow bone in the middle of the front wall of the chest (*thorax*). The collar bones and certain ribs are attached to the sternum.

The 24 *ribs* are semiflexible arches of bone. There are 12 on each side of the chest. The back ends of the 12 pairs of ribs are attached to the 12 *thoracic vertebrae.* Strong ligaments bind the back ends of the ribs to the backbone but allow slight gliding or tilting movements. The front ends of the top seven pairs of ribs are attached to the breastbone by means of cartilage. They are the *true ribs*. The remaining five pairs are the *false ribs*; each of the upper three pairs is attached in front by cartilage to the pair of ribs above, and thus indirectly to the breastbone. The front ends of the last two pairs hang free; they are called *floating ribs*. (See Fig. 11a and 11b.)

The cage-like arrangement of the ribs is an admirable compromise between stability and mobility. The heart and lungs contained within this cage are indispensable organs and must be protected as much as possible. Yet, they cannot be tightly enclosed in a rigid box because the lungs must expand in breathing and the heart must change size when it beats. When a person breathes in *(inspiration)*,

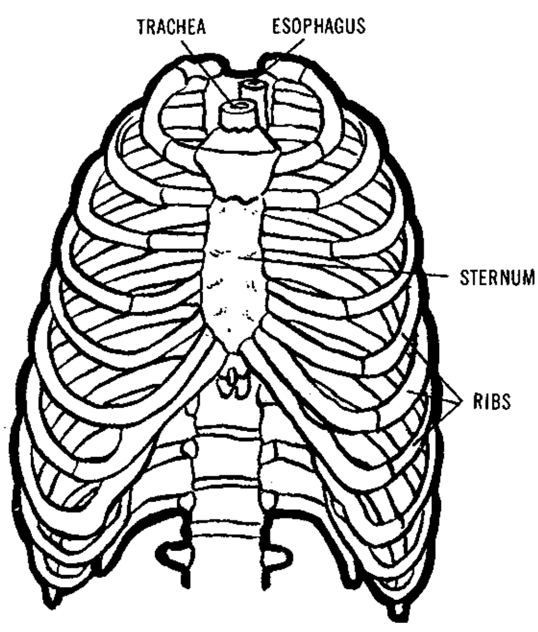

Fig. 1–11a. Ribs and sternum (front view).

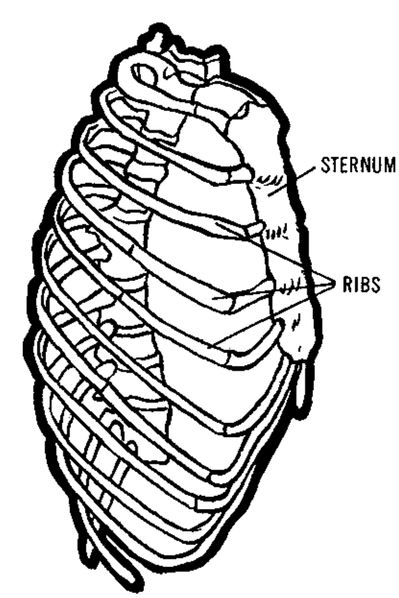

Fig. 1–11b. Ribs and sternum (side view).

muscles lift the ribs and sternum upward and outward, and the big muscle *(diaphragm)* forming the floor of the chest cavity sinks downward, creating a kind of vacuum. This permits the lungs to expand as air rushes in through the nose, mouth, and windpipe *(trachea)*.

Fracture of the sternum or the ribs usually results from crushing or squeezing the chest. A fall, blow, or penetration of the chest wall by a weapon may have the same effect. The chief danger from such injuries is that the lungs or heart may be punctured by the sharp ends of broken ribs.

Appendicular Skeleton

The arms and legs contain no vital organs. A fracture or other injury to them is not likely to cause death, except by a complication such as uncontrolled bleeding, shock, or infection. Permanent crippling can result from an injury to an arm or leg. However, this is less likely today than it was in the days before effective surgery and rehabilitative education. Nonetheless, disfigurement and disability can result from improper handling in first aid. Emergency treatment, if properly given, can minimize this possibility.

The upper and lower extremities are much alike. Each has one long strong bone nearest to the trunk; two long bones lying parallel to each other; and several small bones forming the wrist and hand, or ankle and foot. However, legs and feet, which are for locomotion, are not nearly so flexible as arms and hands, which are for manipulation. Sturdy support for the body's weight, with a reasonable degree of mobility, is all that is required of the legs and feet.

Shoulder Girdle

The collarbone *(clavicle)* and the shoulder blade *(scapula)* form each shoulder girdle. With the muscles which extend from it to the arms, thorax, neck, and head, the shoulder girdle helps attach the arms to the trunk.

Each *clavicle*—a long, slightly double-curved bone—is attached to the breastbone at its inner end and to the shoulder blade at its outer end. Fracture is common because the clavicle lies close to the surface and must absorb blows without protective padding to help absorb trauma.

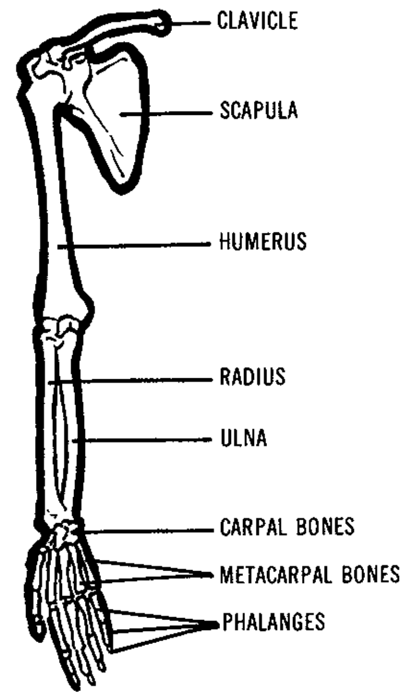

Fig. 1–12. Upper extremity, left (back view).

Each *scapula*—a large, flat, triangular bone—is located over the upper ribs at the back of the thorax. Folded back across its upper portion is a prominent ridge of bone *(the spine of the scapula)*. The ridge ends at the tip of the shoulder, to which the outer end of the collarbone is attached.

Arms

The bone of the upper arm, the *humerus*, is the arm's largest bone. Its shaft is roughly cylindrical; its upper end (the head of the

Table 1–5

THE 64 BONES OF THE UPPER EXTREMITIES*

Name	No.	Location
Clavicle (Collarbone)	2	Shoulder girdle
Scapula (Shoulder blade)	2	Upper back
Humerus	2	Upper arm
Ulna	2	Elbow and little finger side of forearm
Radius	2	Thumb side of forearm
Carpals	16	Wrists
Metacarpals	10	Palm of hands
Phalanges	28	Two in each thumb Three in each finger.

*(See Fig. 1–12.)

humerus) is round; its lower end, flat. The round head fits into a shallow cup in the shoulder blade, forming a ball-and-socket joint. This is the most freely movable joint in the body and is easly dislocated. Dislocation may tear the capsule of the joint *(synovial membrane)* and cause irreparable damage. Improper manipulation during attempts to reduce or "set" the dislocation may add to the damage. Therefore, it is well to treat a dislocation of the shoulder with great care.

The two bones of the forearm (*ulna* and *radius*) lie side by side. The larger ulna is on the little finger side and part of it forms the "elbow bone." The flat, curved lower end of the humerus fits into a big notch at the upper end of the ulna to form the elbow joint. This hinge joint permits movement in one direction only. The radius, shorter and smaller than the ulna, is attached to it near both ends. The wide, lower end of the radius forms a joint with the small bones of the wrist. The ulna is excluded from the wrist joint by the articular disk.

The wrist is composed of eight small, irregularly shaped bones *(carpals)* united by ligaments. Arranged in two rows of four bones each, the carpals articulate with one another as well as with the bones of the forearm and hand. This permits a wide range of motion. Tendons extending from the muscles of the forearm to the bones of the hand and fingers pass down the front and back of the wrist close to the surface. Wrist lacerations may result in cutting these tendons, yielding total or partial immobility of the fingers.

The palm of the hand has five long bones *(metacarpals)*. They articulate at their bases with the lower row of wristbones and with each other. Their heads articulate with the bases of the first row of bones of the fingers.

The 14 bones of the fingers *(phalanges)* give the hand its great flexibility. The first row of bones articulates with the heads of the metacarpals at one end and with the second row of phalanges at the other end. The second row articulates with both the first and third rows. The third, or terminal row, articulates with the second row. (The thumb is an exception; it has only two phalanges.) The thumb is the most important digit. A good thumb and one or two fingers make a far more useful hand than four fingers minus the thumb.

Pelvis and Hips

The two *hipbones*, the *sacrum*, and the *coccyx* form the pelvic girdle *(pelvis)*. Muscles help attach the pelvic bones, the trunk, thighs, and the legs. The pelvis forms the floor of the

Table 1–6

THE 62 BONES OF THE LOWER EXTREMITIES

Name	No.	Location
Innominate (Hipbone)	2	Sides and front of pelvis
Femur (Thighbone)	2	Thigh
Patella (Kneecap)	2	Front of knee joint
Tibia (Shinbone)	2	Front and inner side of leg
Fibula	2	Outer side of leg
Tarsals	14	Ankle and heel of foot
Metatarsals	10	Sole and instep of foot
Phalanges	28	Two in each great toe, three in other toes

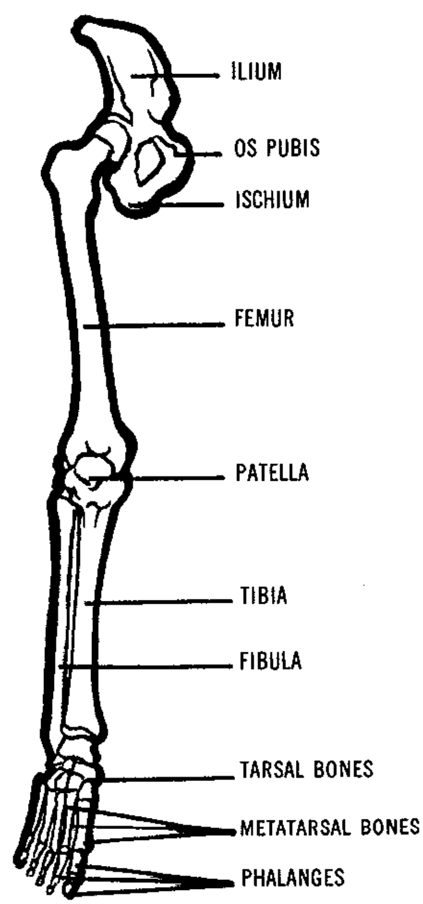

Fig. 1–13. Lower extremity, right (front view).

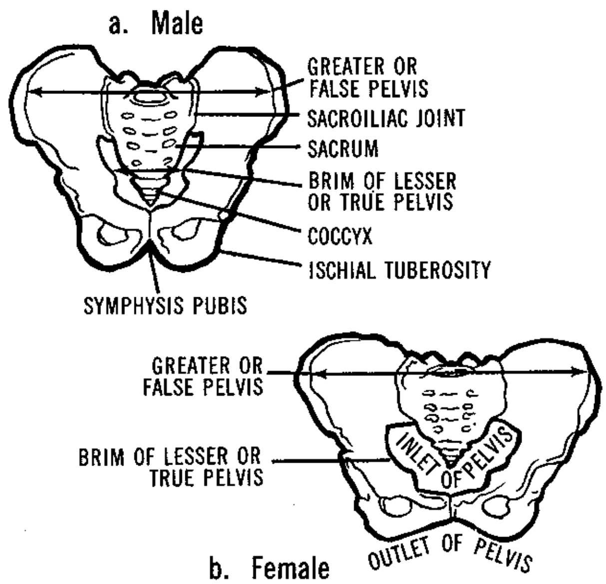

Fig. 1–14. Pelvis and hips.

abdominal cavity. The lower part of the cavity —sometimes called the *pelvic cavity*—holds the bladder, rectum, and internal parts of the reproductive organs. The floor of the pelvic cavity helps to support the intestines.

The *sacrum* and *coccyx,* parts of the spinal column, help form the pelvis. The sacrum is five vertebrae fused together; this wedge-shaped bone is united below with a smaller wedge, the coccyx. This is the "tail" of the vertebral column. (See Fig. 1–14.)

Each hipbone has three parts *(ilium, ischium, pubis)*. The ilium forms the upper prominence of the hip. It joins tightly at the back of the sacrum to form the strong *sacroiliac joint.* The sacroiliac joint does not permit much motion in the lower back region and is subjected to great pressure from the weight of the trunk. This burden is increased when one lifts objects or jumps from a height and lands on his feet. Because of its great strength and stability, the sacroiliac joint is rarely the site of back pain. The joints and muscles of the lower back *(lumbar region)* are much more susceptible to strain. Fracture of the pubis often is associated with injury to the urinary bladder or to the urethra, the tube which drains the bladder.

Thighs and Knees

At the outer side of each hipbone is a deep socket into which the round head of the thighbone *(femur)* fits, forming a ball-and-socket joint. The head of the femur, not as easily dislocated as the less firmly fixed head of the humerus (upper arm bone), is likely to be more difficult to put back into its socket (reduction). The lower end of the femur, like the humerus in the upper arm, is flat and has two knobs *(condyles)*. These articulate with the shinbone *(tibia)* at the knee joint. Although the femur is the longest and strongest bone in the skeleton, its fracture is common. This is always serious because of the difficulties in getting a good position for union between the broken or splintered ends of this large, strong bone. Because of the force required to break the femur, laceration of the surrounding tissues, pain, and blood loss may be unusually extensive.

The knee joint is a strong hinge joint and like the elbow allows angular movement only. The joint is protected and stabilized in the front by the kneecap *(patella)*. The patella is a small triangular-shaped bone in front of the knee joint and within the tendon of the large muscle of the front of the thigh. Because the patella usually receives the force of falls or blows upon the knee, it frequently is bruised and sometimes fractured.

Legs

Anatomically speaking, the word "leg" is used only for that portion of the lower extremity between the knee and the ankle. Its two bones are the *tibia* and the *fibula.* The tibia is at the front and inner side of the leg. Its broad upper surface receives the condyles of the femur to form the knee joint. The lower end, much smaller than the upper end, forms the inner rounded knob of the ankle. The fibula, more slender than the tibia, is at the outer side of the leg parallel to the shinbone. The fibula, not a part of the true knee joint, is attached at the top to the tibia. The fibula is more often fractured alone than is the tibia. (Fig. 1–13.)

Ankles, Feet, and Toes

The ankle joint is the junction of the lower ends of the tibia and fibula with one of the small bones (the *talus)* of the ankle. The seven anklebones *(tarsals)* are bound firmly together by tough ligaments. They are larger and more irregular than the carpal bones in the wrist. The heel bone *(calcaneus)*, largest and strongest of the tarsal bones, transmits the weight of the body to the ground and in walking forms a base for the muscles of the calf of the leg. The heel bone forms the back anchor for the long bony arch or bridge of metatarsals that extends to the base of the toes. The arched formation of the foot gives it the power to absorb shocks and enables it to carry the weight of the body. A person with weak or broken-down arches is said to be flat-footed.

The shape of the foot is roughly a triangle with the apex pointing upward and located at the juncture of the leg and ankle bones. The sole and instep of the foot are formed by the five long *metatarsals*. These articulate with the tarsals and with the front row of toe bones *(phalanges)*. The phalanges forming the toes are similar in number and arrangement to the phalanges forming the fingers. Motion of the ankle, foot, and toes is produced largely by the action of muscles located in the leg. These muscles are connected by long tendons to the bones they move.

MUSCULAR SYSTEM

When the body moves itself, it is due to work performed by muscles. Examples are walking, breathing, the beating of the heart, and the movements of the stomach and intestines. What enables muscle tissue to perform work is its ability to contract—to become shorter and thicker—when stimulated by a

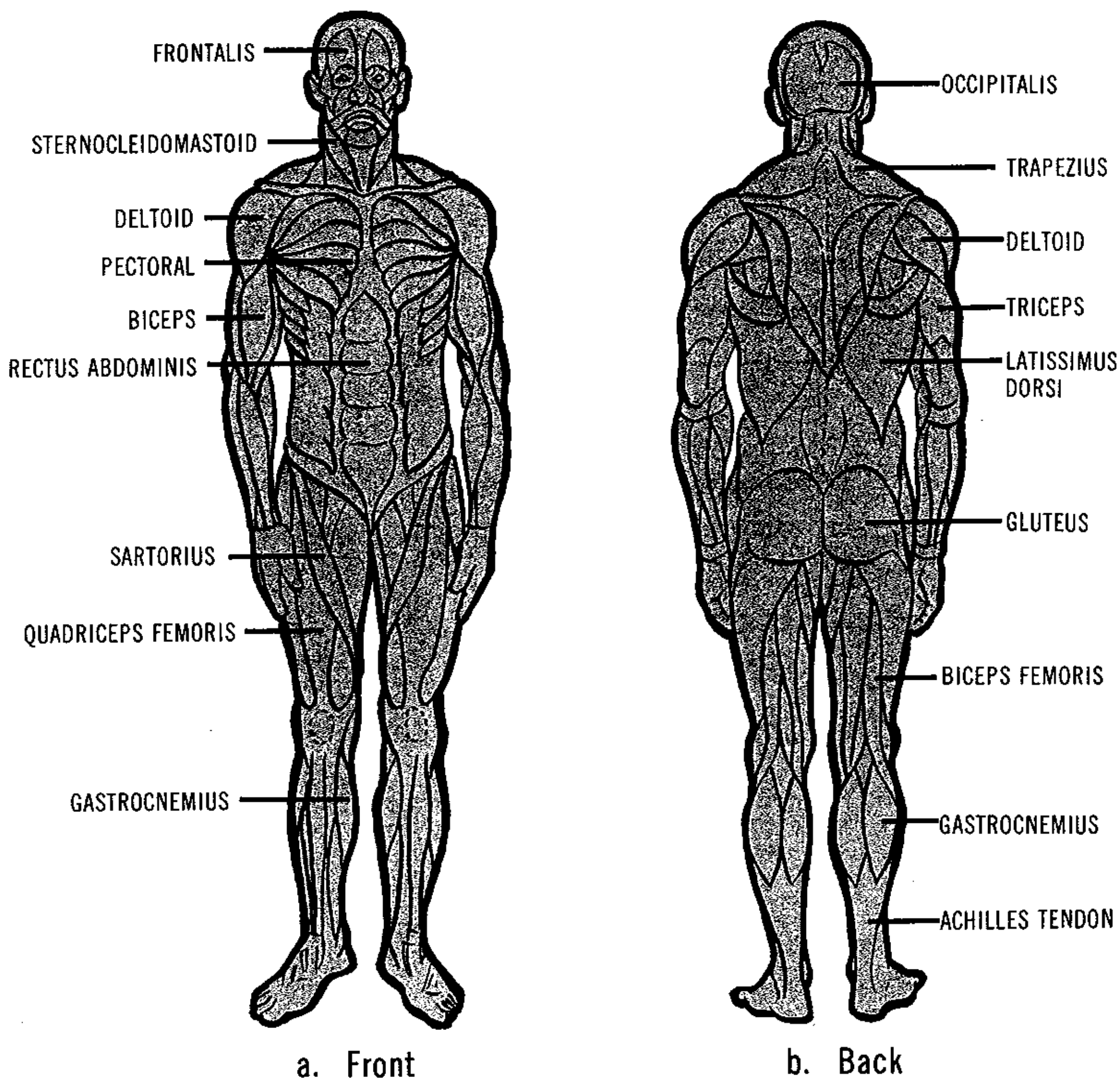

Fig. 1–15. Major muscles of the body.

nerve impulse. The cells of a muscle, usually long and thread-like, are called *fibers*. Each muscle has countless bundles of closely packed, overlapping fibers bound together by connective tissue. The three different kinds of muscles are (1) striated or skeletal muscle *(voluntary)*, (2) smooth muscle *(involuntary)*, and (3) heart muscle *(cardiac)*. They differ in appearance and the specific job they do.

Voluntary Muscle

Voluntary muscles, under the control of a person's will, make possible all deliberate acts: walking, chewing, swallowing, smiling, frowning, talking, or moving the eyeballs. Most voluntary muscles are attached by one or both ends to the skeleton by tendons. However, some muscles are attached to skin, cartilage, and special organs such as the eyeball, or to other muscles as the tongue. (See Fig. 1–15.)

Muscles help to shape the body and to form its walls. In the trunk, they are broad, flat, and expanded, to help form the walls of the cavities they enclose—the abdomen and the chest. In the extremities, the voluntary muscles are long and much more rounded, somewhat resembling spindles. Most voluntary muscles end in tough whitish cords (*tendons* or *leaders)* by which they are attached to the bones they move. Tendons run through sleeves of dense, strong tissue (*fascia*). These are lined with a *synovial membrane* that secretes a lubricating substance, the *synovial fluid*. This makes it easier for the tendon to move when the muscle contracts or relaxes. If the synovial membrane becomes inflamed, stiffness and limitation of motion occur.

When not working, muscles become comparatively slack. But they are never completely relaxed; some fibers are contracting all the time. They always have some tension *(muscle tone)*. Muscle tone, which makes muscles springy and ready for instant action, also has a steadying effect, much as a steady hold on the steering wheel helps to keep a moving vehicle true to its course. When there is no muscle tone, the muscle has *flaccid paralysis*. When in continuous contraction, the muscle has a *spasm* or cramp. When a muscle cannot stop contracting, there is *spastic paralysis*.

Almost all voluntary muscles are arranged in *antagonistic* groups: one group opposes the other. For example, muscles on the front surface of the arm and forearm *(flexors)* bend the arm and hand, while *extensors* on the back surface straighten or extend the arm and hand. When a flexor group contracts to do work, the opposing extensor group automatically relaxes most of its fibers. Muscle groups, operative about a joint, act in much the same way the lines from a deck engine relax or contract in sequence to move a boom in any direction.

Muscular contraction will pull the bone in the direction permitted by the joint. The degree of movement will be limited by the counter-contraction of the antagonist muscle groups attached to the same parts. Working with or against each other in different combinations, muscles produce movements of infinite variety. A simple act like smiling requires the work of many different voluntary muscles.

Muscles can be injured in many ways. Overexerting a muscle may break fibers. Muscles may be bruised, crushed, cut, torn, or otherwise injured, with or without breaking the skin. Muscles injured in any of these ways are quite likely to become swollen, tender, painful, or weak.

Involuntary Muscle

Involuntary muscles are made up of fibers that are larger than most striated fibers. A person has little or no control over these muscles and usually is not conscious of them. Involuntary muscles are in the walls of tubelike organs, ducts, and blood vessels. In the intestines they form much of the walls. Some muscles are in two principal layers (*circular* and *longitudinal*). This arrangement strengthens the tubes and makes possible their rhythmic wavelike movements. The *peristaltic waves* in the intestines propel food through the alimentary canal.

Cardiac Muscle

The walls of the heart have a special kind of muscle. Cardiac muscle is particularly suited for the work the heart must do. It is smooth like involuntary muscle, but is striated like voluntary muscle. Unlike either, it is made up of a cellular meshwork. Heart muscle is able to stimulate itself into contraction, even when disconnected from the central nervous system.

CARDIOVASCULAR SYSTEM

Most cells of the body are anchored in one place. They cannot leave in search of food nor can they get rid of their wastes without help. These services are performed by the *cardiovascular* or *circulatory system.*

Blood is the great common carrier of the body. It carries nutrients and other products from the digestive tract in its *plasma,* and oxygen from the lungs in its *hemoglobin* to cells throughout the body. Also, it transports wastes produced by the cells to the lungs, kidneys, and other *excretory organs* for removal from the body.

Heart

The circulatory system in man is a completely closed circuit of tubelike vessels through which blood flows. The *heart,* by contracting and relaxing, pumps blood through the vessels. It is a powerful, hollow, muscular organ about as big as a man's clenched fist and shaped like a pear. It is in the left center of the chest, just behind the sternum with the apex pointing down and to the left. (See Fig. 1–16.) The heart is divided by a perpendicular wall in the middle. Right and left compartments (*right heart* and *left heart*) are divided into two chambers, *atrium* above, *ventricle* below. A check-valve is located between each atrium and its corresponding ventricle, and at the exit of the major arteries leading out of each ventricle. The opening and shutting of these valves at just the right time in the heartbeat keeps the blood from backing up. (See Fig. 1–17.)

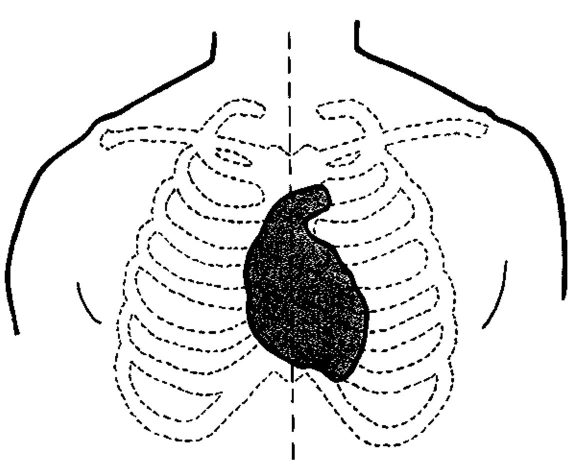

Fig. 1–16. Position of heart in chest cavity.

Blood circulates in two main systems: (a) the *pulmonary circulation* between the lungs and the heart exchanges carbon dioxide and other gas impurities for oxygen; and (b) the *corporeal systemic circulation* that distributes oxygen and food to the body while collecting carbon dioxide and other waste products. At each beat or contraction, the heart pumps blood rich in carbon dioxide and low in oxygen from the right ventricle to the lungs and back to the left atrium of the heart. Blood rich in oxygen freshly obtained from the lungs is pumped from the left ventricle to the rest of the body and back to the right atrium. At each *relaxation* of the heart, blood flows into the left atrium from the lungs and into the right atrium from the rest of the body. To hear the heart, one should put a stethoscope to the patient's chest wall, slightly to the left of the midline and just below the nipple.

Blood Vessels

The *arteries* are elastic, muscular tubes which carry blood away from the heart. They begin at the heart as two large tubes: (a) the *aorta* carries blood to all the body; and (b) the *pulmonary artery* carries blood to the lungs for *carbon dioxide-oxygen exchange.* The aorta divides and subdivides until it ends in networks of extremely fine vessels (*capillaries*) smaller than hairs. Through the thin walls of the capillaries, oxygen and food pass out of the bloodstream into the stationary cells of the body. Into the capillaries the body cells discharge their waste products. In the capillaries of the lungs, carbon dioxide is released and oxygen is absorbed. Capillaries, having reached their limit of subdivision, begin to join together again into veins. These become larger and larger, and finally form major trunks emptying into the right atrium with blood returning from the body, and into the left atrium with blood from the lungs.

It is impossible to prick the normal skin anywhere without puncturing capillaries. Because the flow of blood through the capillaries is relatively very slow and under little pressure, blood merely oozes from a punctured capillary and usually has time to clot, promptly plugging the leak.

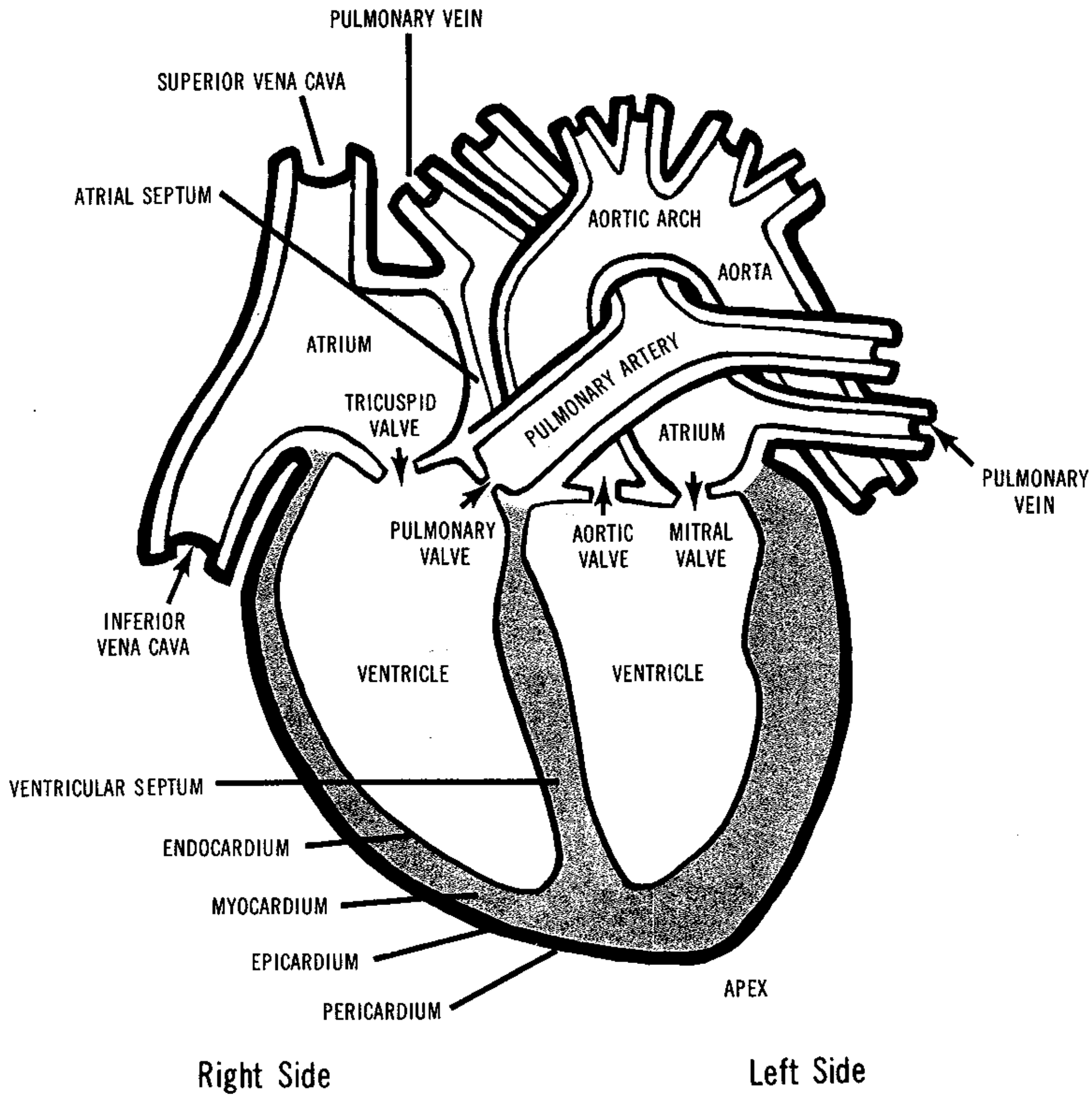

Fig. 1–17. Human heart (diagrammatic).

Pulses

Each time the heart contracts or beats, the surge of blood causes the arteries to expand or stretch. When the heartbeat is completed, the pressure is reduced and the arteries contract or recoil. This expansion and contraction, assisted by the elastic muscle tissue of the arterial walls, can be felt as a *pulse* at points where an artery lies close to the surface of the body. (See Fig. 1–18.)

Because arterial blood moves in waves, blood spurts out when an artery is cut. The spurts become weaker as the arteries grow smaller and smaller. In the capillaries, the pulse disappears. There is no pulse in a vein because the pulse is lost by the time the blood has passed through the capillaries. Hence, blood from a cut vein flows out in a steady stream. It has much less pressure behind it than blood from a cut artery.

Blood Pressure

Blood pressure is a measure of the pressure exerted by the blood on the walls of the flexible arteries. As blood is pumped by the heart into the arteries, the arterial pressure rises; as the heart relaxes between beats, the pressure falls.

The pressure may be high or low according to the resistance offered by the walls to the

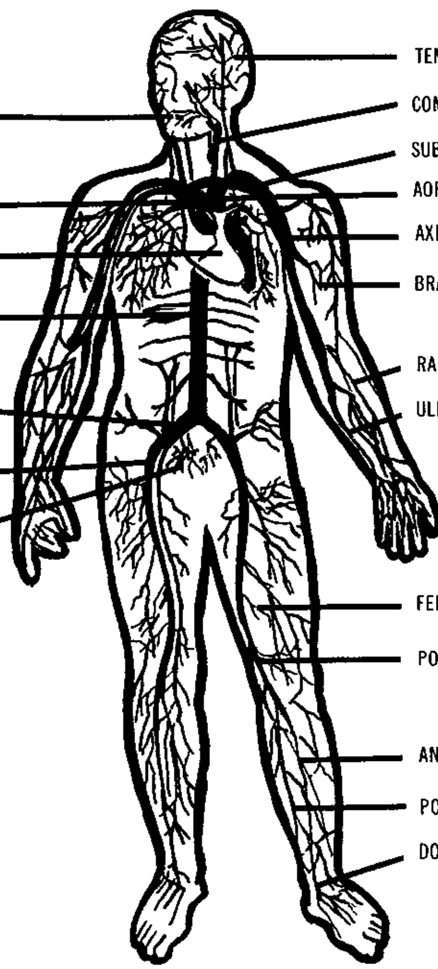

Fig. 1–18. Circulatory system (diagrammatic)—Important arteries named.

passage of blood. This difference in resistance may be due to several causes. For instance, if blood in the system does not fill it, as following hemorrhage, the pressure will be low *(hypotension)*. But if the walls of the arteries have become hard and cannot expand readily, the pressure will be higher than normal. High blood pressure *(hypertension)* may be a symptom of a serious disease.

Blood

Blood makes up about 8 percent of the body's weight. A man weighing 150 pounds, for example, has about 12 pounds of blood. A pound of blood equals about 500 ml or a *unit* of blood, as it is measured for transfusion. Blood, extremely complex, has liquid and solid portions. The liquid portion is called plasma. The solid portion, which is transported by the plasma, includes microscopic, disk-like red blood cells (erythrocytes); slightly larger, irregularly-shaped, white blood cells (leukocytes); and an immense number of smaller bodies called blood platelets (thrombocytes). The ratio of red blood cells to white blood cells in normal blood is about 700:1.

Plasma, the liquid part of the blood, is a viscous fluid about 90 percent water, in which minerals, sugar, and other materials are dissolved. Plasma carries food materials picked up from the digestive tract and transports them to the body cells. Also, it carries waste materials produced by cells to the kidneys, digestive tract, sweat glands, and lungs for elimination *(excretion)* in urine, feces, sweat, and expired breath.

The *red blood cells*, 4½ to 5½ million per cubic millimeter of blood, contain an iron compound (*hemoglobin*) which absorbs oxygen from the lungs and unloads it in the tissues. Oxygen turns hemoglobin bright red, which is why arterial blood—blood on the way from the lungs to the tissues—is bright red. Venous blood, full of carbon dioxide, is a darker brownish-red.

The *white blood cells,* 5,000 to 9,000 per cubic millimeter, form the body's first line of defense against invading bacteria. The cells can go wherever needed within the body, as for example a wound in the skin, or to any other tissue that is diseased or injured. *Pus,* a sign of wound infection, gets its yellowish-white color from the innumerable white blood cells that fight the invading bacteria.

Blood platelets, 250,000 to 450,000 per cubic millimeter of blood, play an important role in clot formation. If blood plasma did not clot at the site of a wound, the slightest cut or abrasion would produce death from bleeding. A clot plugs the openings through which blood escapes from punctured blood vessels. Bleeding from large blood vessels may be too rapid to permit the formation of a clot. Various emergency measures must be taken to control such severe bleeding. *Hemorrhage* is the term for profuse bleeding.

LYMPHATIC SYSTEM

The human body is fed and defended from bacterial infection by the *lymphatic system.*

All substances exchanged between blood and body cells are transported in a fluid called *lymph.* Part of blood plasma, lymph seeps through the capillary walls, constantly feeding and bathing the tissues. The lymph returns to the bloodstream through the walls of the capillaries, by way of a system of thin-walled vessels *(lymphatics).* Clusters of lymph glands *(lymph nodes)* act as traps in the lymphatics for bacteria and other tiny particles. In the lymph nodes, these particles are attacked and destroyed by white blood cells. Infected lymph glands become enlarged, and can be felt as tender lumps in the neck, armpits, groin, and bend of the elbow. The *bubo* (inflammatory swelling) that may follow venereal diseases is a cluster of infected lymph glands in the groin. (See Fig. 1–19.)

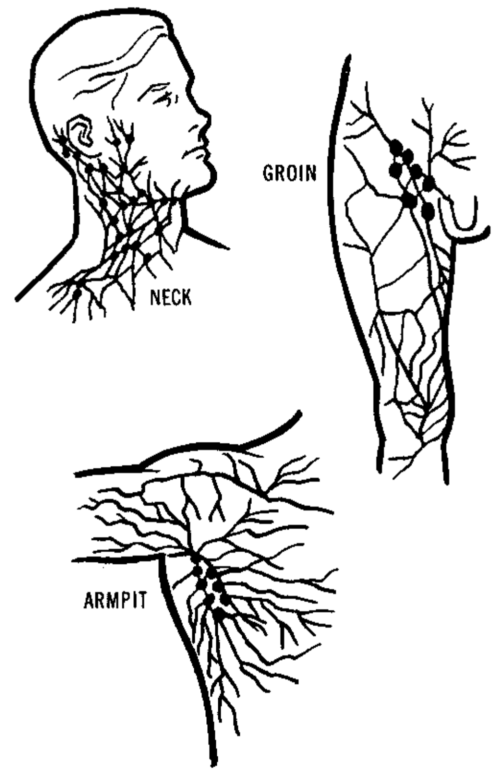

Fig. 1–19. Lymph nodes (main groups).

The lymphatic system includes:

1. A *system of tiny ducts* with walls one-cell thick (a capillary network).
2. *Larger vessels* which funnel lymph into the cardiovascular system.
3. *Lymph nodes* which act as filters and produce certain germ-fighting white blood cells (lymphocytes).
4. *Tonsils and adenoids:* tissues that strain out foreign particles.
5. *Spleen:* Over the years various functions have been attributed to the spleen, which is the largest lymphatic organ in the body. Now it is thought to enter into blood formation—especially red cells during fetal life and later in certain emergencies; and the production of some types of white blood cells throughout life. It acts as a reservoir of blood and enters into the destruction of worn-out red blood cells. There is some evidence that it may control the production of cells by the bone marrow.

The spleen is located beneath the diaphragm, behind and to the left of the stomach, in the upper left quadrant of the abdomen. Because it lies close to the lower left ribs, fracturing them sometimes injures the spleen. Also, it may be ruptured by a severe blow, without fracture. A ruptured spleen will produce internal hemorrhage which may lead to death. A spleen can be removed surgically without seriously interfering with normal living. (See Fig. 1–22.)

RESPIRATORY SYSTEM

The body may store food to last for several weeks and water to last for several days, but it can store only enough oxygen for a few minutes. Ordinarily this does not matter because we have only to inhale air to get the oxygen we need. If the oxygen supply of the body is cut off, as in drowning, choking, or smothering, death will come in about five minutes unless oxygen intake is restored. Oxygen from air is made available to the blood through the respiratory system and then to the body cells by the circulatory system. (Fig. 1–20.)

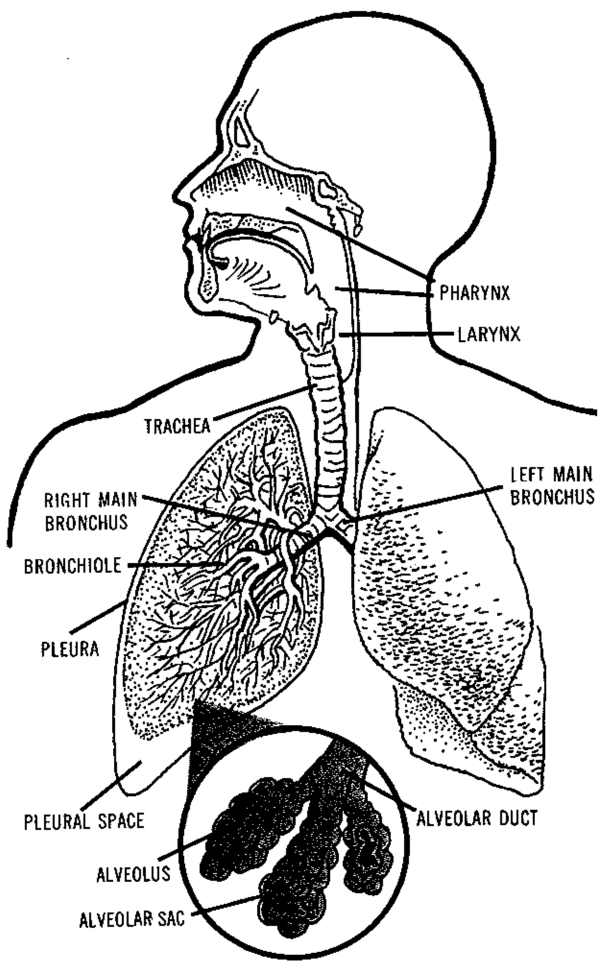

Fig. 1–20. Respiratory system.

Nasal Passages

Air normally enters the body through the nostrils. It is warmed, moistened, and filtered as it flows over the damp, sticky lining *(mucous membrane)* of the nose. When a person breathes through the mouth instead of the nose, there is less filtration and warming.

The nose is divided into two crooked passages by a wall *(septum)* of bone and cartilage. Each side of the nose has bones shaped like two inverted cones *(turbinates)*. These protect the lungs from foreign body contamination, while warming and moistening the air. Breath passing through the nasal passages enters the nasal portion of the pharynx *(nasopharynx)*.

Pharynx and Trachea

From the back of the nose or mouth, the air enters the throat *(pharynx)*. The pharynx is a common passageway for food and air. (See Fig. 1–21.) At its lower end it divides into two passageways, one for food and the other for air. Food is routed by muscular control in the back of the throat to the food tube *(esophagus)* which leads to the stomach, and air from the pharynx to the windpipe *(trachea)* which leads to the lungs. The trachea and the esophagus are separated by a small cartilagenous flap of tissue (the *epiglottis*) which acts as a kind of valve that closes the trachea while food is being swallowed. At other times the trachea remains open to permit breathing. Usually this controlled diversion works automatically to keep food out of the trachea and air from going into the esophagus. However, when the epiglottis fails to close, food or liquids can enter the larynx instead of the esophagus.

During unconsciousness normal swallowing controls do not operate. *If liquid is poured into the mouth of an unconscious person to try to revive him, it may get into his windpipe and cause suffocation.* Foreign objects, as false teeth or a piece of food, may lodge in the throat or windpipe and cut off the passage of air.

In the upper two inches of the trachea, just below the epiglottis, is the voice box *(larynx)* which contains the vocal cords. In the front of the throat the larynx *(Adam's apple)* can be felt.

Lungs

The trachea branches into two main tubes (*bronchial tubes* or *bronchi*), one for each lung. Each *bronchus* divides and subdivides somewhat like the branches of a tree. Finally, the smallest ones end in thousands of tiny pouches (*air sacs*), just as the twigs of a tree end in leaves. Each air sac is enclosed in a network of capillaries. The adjoining walls of the air sacs and the walls of the capillaries are very thin. Through these walls, the oxygen combines with hemoglobin in red blood cells to form *oxyhemoglobin*, which is carried to all parts of the body. Carbon dioxide and certain other waste gases in the blood move across the capillary walls into the air sacs and are exhaled from the body. Tobacco smoke and certain other inhaled irritants cause the partitions between the air sacs to be destroyed, resulting in shortness of breath and eventually a disease called *emphysema*.

The lungs are very light—somewhat like large sponges. With the heart they occupy most of the chest cavity *(thoracic cavity)*, which is divided into three sections, all separated from each other by a pleural membrane. The lungs are enclosed in a double-layered sac *(pleural sac)*; the inner layer *(visceral pleura)* covers the lungs; the outer layer *(parietal pleura)* lines all of the chest cavity. The space between the pleural membranes contains fluid *(pleural fluid)* which acts as a lubricant to reduce friction. Inflammation of the pleurae (pleurisy) may cause friction, fever, and a stabbing pain with each breath. The lungs are open to attack by viruses and other microorganisms, notably those causing *bronchitis*, *pneumonia*, and *tuberculosis*.

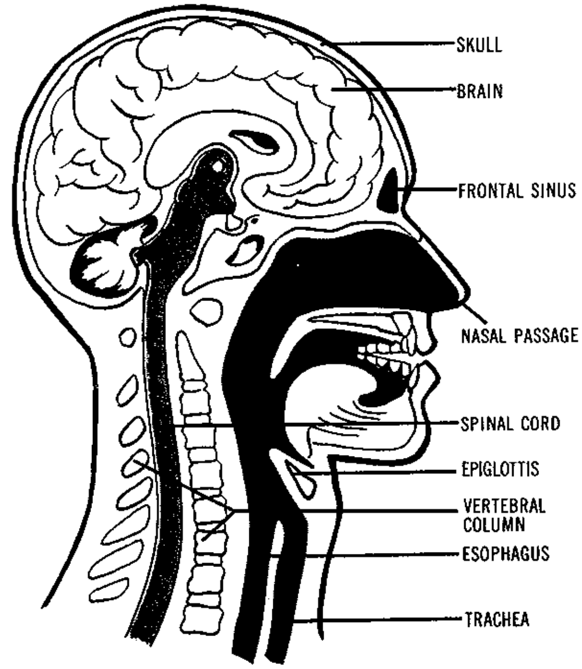

Fig. 1–21. Head and neck (sagittal plane section).

Mechanics of Breathing

The passage of air into and out of the lungs is called *respiration*. Breathing in is called *inspiration* or inhalation; breathing out is *expiration* or exhalation.

Respiration is a mechanical process brought about by alternately increasing and decreasing the size of the chest cavity. During inspiration, the diaphragm is drawn downward, and the up-and-down dimension of the chest cavity is increased. At the same time, muscles attached to the chest wall tighten and lift the ribs and sternum upward and outward, increasing the front-to-back and side-to-side diameters of the chest. A relative vacuum in the respiratory system occurs. By way of the nose, mouth, trachea, and bronchi, air enters the lungs, which expand to fill the enlarged chest cavity and the air sacs receive fresh air. Muscles can close the larynx to hold the breath. During expiration, the muscles of the chest relax; the larynx opens to release the air trapped in the "pulmonary tree." Atmospheric pressure on the chest wall forces the ribs to fall, decreasing the size of the chest cavity. At the same time, the abdominal muscles contract, the abdominal contents press upward on the relaxed diaphragm and it domes. This further decreases the size of the chest cavity, forcing out the same volume of air that just had been taken in.

The average rate of breathing in an adult at rest is from 16 to 18 complete respirations (inspiration-expiration) per minute. Normally the rate is less when a person is lying down; faster when he is exercising vigorously.

Normally, the rate of breathing is controlled by a nerve center in the brain (the *respiratory center*). When a person does hard muscular work, the lungs cannot get rid of carbon dioxide or take in oxygen fast enough at the normal rate. As carbon dioxide increases in the blood and tissues, the respiratory center sends impulses along its nerves to cause deeper and more rapid respirations. At the same time, the heart rate increases. A greater supply of oxygen becomes available to the blood and lungs, because more blood moves through the lungs as a result of the increased heart rate. For the same reason, more carbon dioxide is discharged from the lungs.

DIGESTIVE SYSTEM

The process by which food is broken mechanically and chemically into a form the cells can use is *digestion.* This takes place mainly in the alimentary canal *(gastrointestinal tract)*, which extends through the body from the mouth to the anus and includes the esophagus, stomach, intestines, and rectum. (See Fig. 1–22.)

Abdominal Cavity

Except for the mouth and esophagus, the abdomen contains the major organs of the gastrointestinal tract. (See Fig. 1–22.) The abdominal cavity is well protected above by the thorax, below by the heavy ring of pelvic bones, and at the sides and in the back by thick tough muscles, the lower ribs, and the spinal column. It is protected in front by flat muscular layers, which for greater strength run in different directions in the abdominal wall.

Contraction of the abdominal muscles and diaphragm puts pressure on the abdominal contents from the sides, front, and above. This pressure helps defecation, urination, and vomiting. Occasionally, there are weaknesses in the abdominal wall which may "give" under pressure. These weaknesses are at points of some anatomic peculiarity, such as where two bundles of muscles cross at an angle to each other. Under sufficient pressure, the abdominal contents may bulge into or through the muscle wall but not through the skin. This is a rupture *(hernia)*. Most hernias occur in the groins *(inguinal hernias)*. A rupture at the navel *(umbilicus)* is called an *umbilical hernia.* Hernias also may occur in many other places, both superficially and deep in the abdominal cavity.

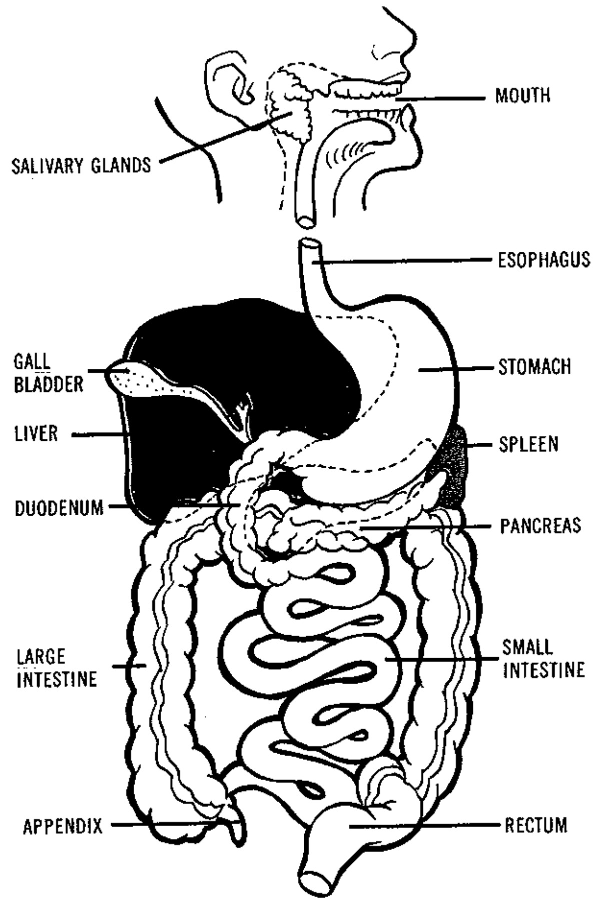

Fig. 1–22. Digestive system.

Peritoneum

The peritoneum is a sheathlike membrane in the abdominal cavity that consists of two layers. The outer layer *(parietal)* lines the walls of the abdominal cavity and the inner layer *(visceral)* surrounds and helps support some of the abdominal organs. Where the surfaces of these two layers contact each other, they secrete *peritoneal fluid,* a lubricant that prevents the layers from sticking together to form *adhesions.*

Alimentary Canal

The alimentary canal is divided into four specific parts by ringlike bands of muscles *(sphincters)*. These are at the junction of (1) the esophagus and the stomach (the *cardiac sphincter)*; (2) the stomach and small intestine *(pylorus)*; (3) the small intestine and the large intestine *(ileocecal valve)*; and (4) the end of the canal *(anal sphincter* or *anus)*. When a sphincter contracts, it closes the canal at that point so that its contents cannot pass through. The only sphincter under voluntary control is the anal sphincter, allowing control of the feces.

Food is pushed along the alimentary canal by contraction of the involuntary muscles in its wall. This *peristalsis*, besides moving food along, helps mix food with digestive juices in the stomach and small intestine. The wavelike motion of peristalsis usually is in one direction, away from the mouth; however, in vomiting, or when the bowel becomes obstructed, there may be a *reverse peristalsis* and the intestinal contents are ejected by way of the mouth.

Digestion begins in the mouth. Food is broken down and mixed with *saliva* by the action of the teeth, jaw and cheek muscles, and the tongue. Saliva, secreted by the *salivary glands*, contains an *enzyme*, a chemical which starts the digestion of starch. Later in the small intestine partly digested starch is turned into a sugar *(glucose)* which can be used by the body. Other enzymes are produced in the stomach, liver, pancreas, and small intestine for the digestion of each of the three principal components of food: *proteins* (found principally in meat, beans, and dairy products); *carbohydrates* (starches and sugars); and *fats* (both animal and vegetable).

Esophagus

Food passes from the mouth down the back of the throat *(pharynx)* and into the *esophagus*. A fairly straight, narrow, muscular tube, the esophagus passes through the chest just in front of the spinal column and into the abdomen. Through an opening in the diaphragm, it enters the stomach. Food is started down the esophagus by the action of the voluntary swallowing muscles of the mouth and pharynx. Then, peristalsis takes over. Pain sometimes occurs when the peristaltic wave presses on the food mass *(bolus)*, instead of behind it. At the lower end of the esophagus, the cardiac sphincter opens and food passes into the stomach.

Stomach

The *stomach*, a sac or pouch, is in the left, upper part of the abdomen, just below the diaphragm. (See Fig. 1–22.) It increases in size as food enters, and decreases as food passes out. The stomach holds food until it is acidified, liquified, mixed, and digested sufficiently to pass on into the small intestine. Digestion in the stomach is by gastric juices *(digestive enzymes)*. By peristalsis, the stomach mixes the food with the gastric juices. Too much hydrochloric acid causes acid indigestion *(hyperacidity)*. Haste, worry, emotional tension, tobacco, and alcohol appear to interfere with digestion. If not treated properly, hyperacidity may lead to a gastric or duodenal ulcer.

Small Intestine

From the lower end of the stomach, partially digested food *(chyme)* moves, a little at a time, through the pyloric sphincter into the small intestine. This narrow tube, about one inch in diameter and 23 feet long in the adult, extends from the stomach to the large intestine, joining the latter at the ileocecal valve in the lower right quadrant of the abdominal cavity. The upper part of the small intestine, the first 10 or 12 inches nearest the stomach, is the *duodenum*. Juices secreted by the liver and pancreas are delivered through ducts to the duodenum. These alkaline juices change the chyme from an acid to a nonacid state. The mucous membrane lining the small intestine has many tiny folds. These increase the surface in contact with the food and help in the absorption of digested food from the intestine into the blood and lymph.

Liver

The *liver*, the largest gland in the body, secretes *bile* and converts and stores sugar for use by muscles and other tissues. The liver is located in the upper right quadrant of the abdominal cavity. Its upper rounded surface fits closely into the under surface of the diaphragm, and part of its left side fits over the lower end of the stomach. Bile is concentrated and stored in a small sac *(gallbladder)*, from which it pours into the duodenum through the *bile duct* where it aids in digestion. Gallstones may form in the gallbladder by the crystallization of one or more ingredients of bile. The passage of a stone through the bile duct often causes severe pain *(gallstone* or *biliary colic)*. Gallstones may plug the bile duct, causing a back-up of bile in the liver. *Jaundice,* due to the presence of an abnormal amount of bile in the blood, gives a yellowish tinge to the skin, whites of the eyes, and membranes beneath the tongue.

There is a special system *(portal circulation)* for the transport of digested and absorbed foods from the intestines to the liver. The veins from most of the intestinal tract do not return blood directly to the heart, but convey it first to the liver. Capillaries in the liver bring this portal blood into close contact with cells that alter the partly converted food products into special materials for use by the body. These liver capillaries then funnel into a network of veins *(hepatic veins)* and the *inferior vena cava,* which delivers all the blood from the liver and the rest of the lower part of the body to the right atrium of the heart.

In certain diseases, the liver cells degenerate and are replaced by scar tissue. In this condition, *cirrhosis of the liver,* commonly seen in chronic alcoholics, blood cannot move easily through the liver. Pressure in the portal veins increases *(portal hypertension).* The portal blood may be sent on detours instead of passing normally through the liver. This may produce dilated veins (*varicose veins* or *varices*) in the stomach and esophagus, about the anus (*hemorrhoids* or *piles),* and even in the abdominal wall. The dilated veins in the stomach or esophagus are likely to rupture, with severe and often fatal hemorrhage.

Pancreas

The *pancreas* is a fish-shaped gland in the upper left quadrant of the abdominal cavity, behind the stomach and in front of the spinal column. (See Fig. 1–22.) It manufactures two important substances: (1) *pancreatic juice,* which passes from the pancreas into the duodenum through the pancreatic duct and is essential to the digestion of proteins, carbohydrates, and fats; and (2) *insulin,* which is absorbed directly from the gland into the bloodstream. An internal (or *endocrine*) secretion, insulin helps regulate the body's use and storage of sugar. The production of insufficient insulin results in *diabetes.*

Large Intestine and Rectum

Food not digested and absorbed by the small intestine passes into the *large intestine,* or *colon,* through the *ileocecal valve* in the lower right quadrant of the abdomen. The small intestine opens into the large intestine about two or three inches from the colon's beginning. This initial section of the large intestine is a kind of blind pouch called the *cecum.* At the end of the cecum is a narrow, wormlike tube (the *appendix*). Inflammation of the appendix is called *appendicitis.* The large intestine, about 2½ inches in diameter and 4 or 5 feet long, looks like a squared horseshoe. Beginning in the lower right quadrant of the abdomen, the large intestine goes up the right side (*ascending colon*) and crosses (*transverse colon*) to the left side; then goes down the left side *(descending colon).* In the lower left quadrant it makes a few turns to form the lower bowel *(sigmoid colon).* The large intestine or colon ends in the *rectum.*

The large intestine holds food residue and waste (*feces*) until some of the water is absorbed, reducing its bulk and fluidity. This absorption by the large intestine salvages large quantities of water which if lost by the body could be life-threatening.

The *rectum,* that portion of the large intestine just above the *anus,* is about five inches long. It ends in the *anal canal,* which terminates the alimentary canal. The anal canal, only about 1½ inches long, is guarded by the *anal sphincter,* which opens during a bowel movement (*defecation*).

URINARY SYSTEM

The urinary system produces urine to rid the body of certain wastes that result from cellular action. Urine normally is composed of water and salts, but in certain illnesses, sugar, albumin (a protein), cells, and cellular debris also may be present. Identifying the composition of urine helps to diagnose some illnesses. Elimination of waste matter from the body is called *excretion.*

The urinary system includes two *kidneys* (where the urine is formed); two *ureters* (tubes to carry urine from the kidneys to the bladder); the *bladder* (a reservoir for urine

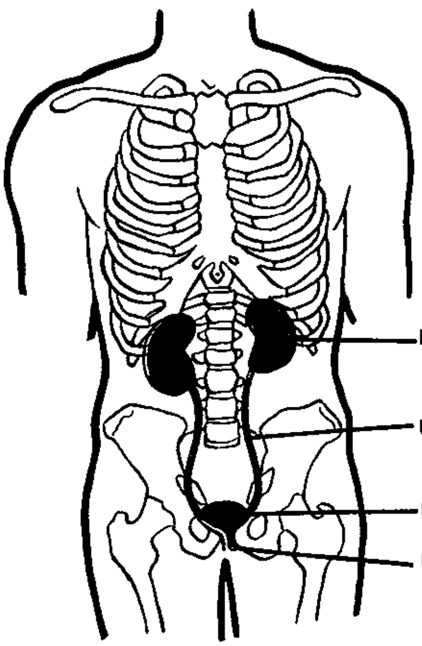

Fig. 1–23. Urinary system.

until discharged); and the *urethra* (the tube which carries the urine from the bladder to the outside of the body). (See Fig. 1–23.)

Kidneys

The *kidneys*, bean-shaped organs weighing about one-half pound each, are on either side of the spinal column in both upper quadrants of the abdominal cavity, about the level of the last lower rib. The kidneys are deeply imbedded in fatty tissue, well protected by heavy muscles of the back, and are seldom injured except by severe trauma.

The kidneys purify blood and maintain a proper fluid and chemical balance for the body. About 96 percent of urine is water. The quantity (over one liter daily) of urine excreted and the analysis of its contents *(urinalysis)* inform the physician whether the kidneys are working properly. When the kidneys fail, the body is poisoned by wastes which cannot be excreted. This *uremia*, if not treated properly, may lead to death.

Bladder and Urethra

The *bladder* is a muscular sac. When empty, it lies entirely within the pelvis behind and beneath the pubis. Because of its vulnerable location, especially when distended, the bladder sometimes is punctured, ruptured, or otherwise injured when the abdomen is struck heavily or the pubis is broken.

The *urethra* is the canal which empties the urine from the bladder. It also carries male seminal fluid *(semen)* on ejaculation. Through the external opening of the urethra, infections from bacteria and other organisms may travel to the bladder, to the kidneys by way of the ureters, or the testicles through the seminal ducts.

REPRODUCTIVE SYSTEM

The reproductive systems in the male and female consist of complementary organs whose function is to accomplish reproduction and produce a new human being. The male, who provides the male germ cell (the *sperm*), and the female, who provides the female germ cell (the *ovum*), contribute the genes that determine the hereditary characteristics of the baby. Combination of a single sperm with a single ovum forms a fertilized ovum that can grow into an *embryo*, then into a *fetus*, and finally a newborn baby.

Male Reproductive System

The reproductive system of the male includes the two *testes* (singular, *testis*), a *duct system, accessory glands*, and the *penis*.

The *testes* are two oval glands, which produce sperm and male hormones and are enclosed within a skin-covered pouch called the *scrotum*. The structures that form the *duct system* are the *epididymides, vas deferens, ejaculatory duct*, and the *urethra*.

Each *epididymis*, located along the top and side of each testis, consists of a single tightly coiled tube which connects the testis with the

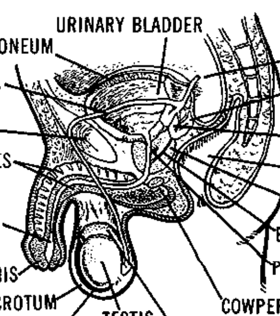

Fig. 1–24. Reproductive system (male).

vas deferens. The *vas deferens* extends upward inside the *spermatic cord*, a cylindrical casing of white fibrous tissue that also encloses blood vessels, lymphatics, and nerves, through the *inguinal canal* into the abdominal cavity. It joins the duct from the *seminal vesicle* to form the ejaculatory duct, a short tube which passes through the prostate gland and ends in the urethra.

The accessory reproductive glands of the male are the *seminal vesicles*, the *prostate gland*, and the *bulbourethral glands* or Cowper's glands.

The *seminal vesicles* are two membranous pouches lying above the prostate and behind the bladder. They secrete the viscous liquid portion of the semen.

The *prostate* is a chestnut-size, glandular body which surrounds the neck of the bladder and part of the urethra. The prostate adds a thin alkaline secretion to the seminal fluid. In older men the prostate frequently enlarges in size. As it enlarges, it compresses the urethra so that urine cannot pass readily through the tube.

The two small pea-shaped *bulbourethral glands* lie below the prostate gland on either side of the urethra. They secrete an alkaline fluid which lubricates the urethra.

The *penis* serves a double function: it contains the urethra, the terminal duct for both the urinary and reproductive systems; and is the organ of copulation by means of which sperm cells are introduced into the female vagina. The penis is composed of three cylindrical masses of erectile tissue that stiffen when engorged with blood. The head of the penis (*glans penis*), highly sensitive, is covered by a foreskin *(prepuce)*. The scrotum and the penis constitute the *external genitals* of the male. (See Fig. 1–24.)

Female Reproductive System

The female reproductive system consists of two ovaries, two uterine *(fallopian)* tubes, the *uterus*, the *vagina*, and the *external genitals*. (See Fig. 1–25.) The accessory organs are the breasts *(mammary glands)*.

There is an *ovary* on each side of the uterus, below and behind the fallopian tubes. The ovary, the female counterpart of the testis, is oval and covered by a special type of tissue *(germinal epithelium)*. Beneath this tissue covering are numerous round transparent vesicles (sacs), each with an ovum in a different stage of maturation. When mature, an ovum ruptures into the abdominal cavity *(ovulation)*. Ovulation usually occurs every 28 days from puberty to menopause. The ovaries also produce hormones that control the implantation of the fertilized egg in the uterus, stimulate the growth of the mammary glands, and stop ovulation during pregnancy.

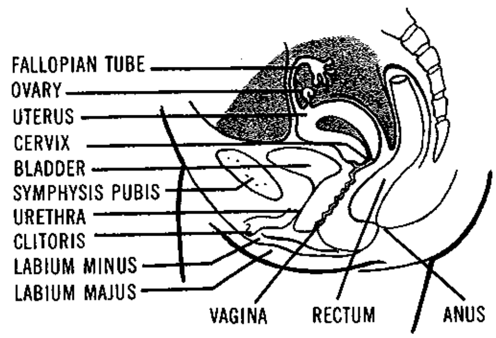

Fig. 1–25. Reproductive system (female).

The *fallopian tubes*, about four inches long, enter the uterus from the upper outer wall on the right and on the left. The tubes serve as ducts for the germ cells *(ova)* even though they are not actually connected to the ovaries. Near the ovary, each tube has a number of finger-like projections which sweep an ovum into the tube and thence to the uterus. Fertilization normally occurs in the fallopian tubes.

The *uterus*, a pear-shaped, hollow, muscular, thick-walled organ is composed of two parts: an upper portion, the *body*, and a lower, narrow section, the *cervix*, which extends into the upper vagina.

The uterus has several functions: *menstruation*, the monthly shedding of the lining of the uterus; *pregnancy*, when the embryo implants itself in the uterus a few days after fertilization and lives there throughout the fetal period; and *labor*, the powerful, rhythmic contractions which result in expulsion of the fetus from the mother at birth.

The *vagina* is a musculo-membranous collapsible tube located behind the bladder and urethra and in front of the rectum. The vagina is the site of copulation in the female. Also, it serves as the lower part of the birth canal and as the excretory duct for the menstrual flow.

The external genital structures—referred to collectively as the *vulva*—include the *mons pubis*, the *labia majora*, the *labia minora*, the *clitoris*, the *vestibule of the vagina*, and the *greater vestibular glands*, or *Bartholin's glands*.

The *mons pubis*, a fatty pad lying in front of the pubic bone, is covered with hair after puberty. Extending downward from the mons are two fleshy flaps of skin (*labia majora* and *labia minora*). Between them is the *clitoris*. Like the penis, it contains erectile tissue and is highly sensitive to stimulation. The vestibule of the vagina is in the area situated posterior to the clitoris and between the labia minora. The urethra opens into this space anteriorly and the vagina opens into it posteriorly. The Bartholin's glands open on either side of the vaginal orifice. They secrete a lubricating fluid. These glands are of clinical importance because they may become infected.

NERVOUS SYSTEM

The nervous system is a very complex collection of nerve cells (*neurons*) that coordinate the work of all parts of the human body and keep the individual in touch with the outside world. Neurons receive stimuli from the environment and transmit impulses to nerve centers in the brain and spinal cord. Then by a complicated process of thinking (reasoning), plus reflex and automatic reactions, they produce nerve impulses that regulate and coordinate all bodily movements and functions, and govern behavior and consciousness.

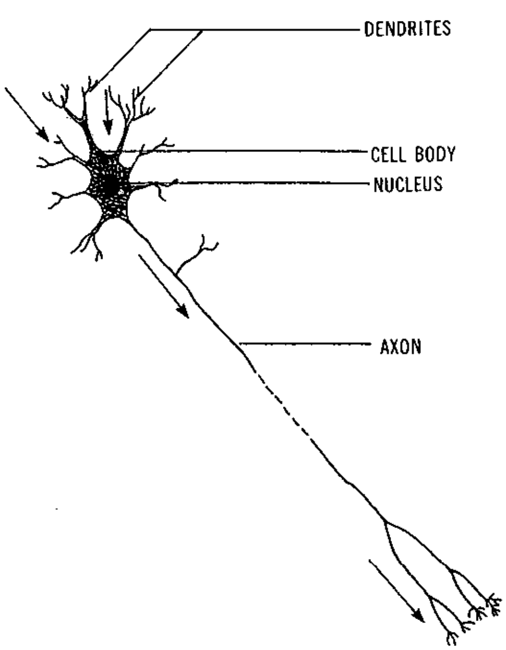

Fig. 1–26. Nerve cell (neuron). Diagrammatic. Arrows show direction of impulse.

Nerve Cells

The nervous system's basic unit, the *neuron*, transmits messages in the form of electrochemical impulses to other neurons. A neuron consists of a central cell body with threadlike extensions (processes)—an *axon* with several *dendrities*. (See Fig. 1–26.) Impulses are carried toward the cell body by dendrites. A single process called an axon transmits impulses away from the cell body. Axons and dendrites of the body's nerve cells never touch each other; there is a space or gap (a *synapse*) between them over which nerve impulses are relayed by electrochemical means. A group of nerve cells is called a *ganglion* (pl. ganglia).

In terms of function, neurons may be classed as (1) *sensory* or *afferent nerves* that carry messages toward the brain or spinal cord; (2) *motor neurons* or *efferent nerves* that carry impulses from the brain or spinal cord to *muscles* to produce various actions; and (3) *mixed nerves* that transmit impulses in both directions at once.

Once nerve cells are destroyed, the body cannot regenerate them. However, some limited nerve repair is possible as long as the vital cell body is intact. If a nerve fiber is cut or injured, the section attached to the cell body remains alive, but the part beyond the injury withers away. At times the live remnant may extend itself beyond the withered section to restore function.

Classification

The nervous system can be discussed in different ways. From a structural standpoint, there is the (1) *central or cerebrospinal nervous system* that includes the brain and spinal cord; and (2) the *peripheral nervous system*, a network of nerve cells that originates in the brain and spinal cord and extends to all parts of the body, including muscles, surface of the skin, and the special sense organs as the eye and ear. The peripheral nervous system is further subdivided into the *voluntary* and *autonomic (involuntary) nervous systems*.

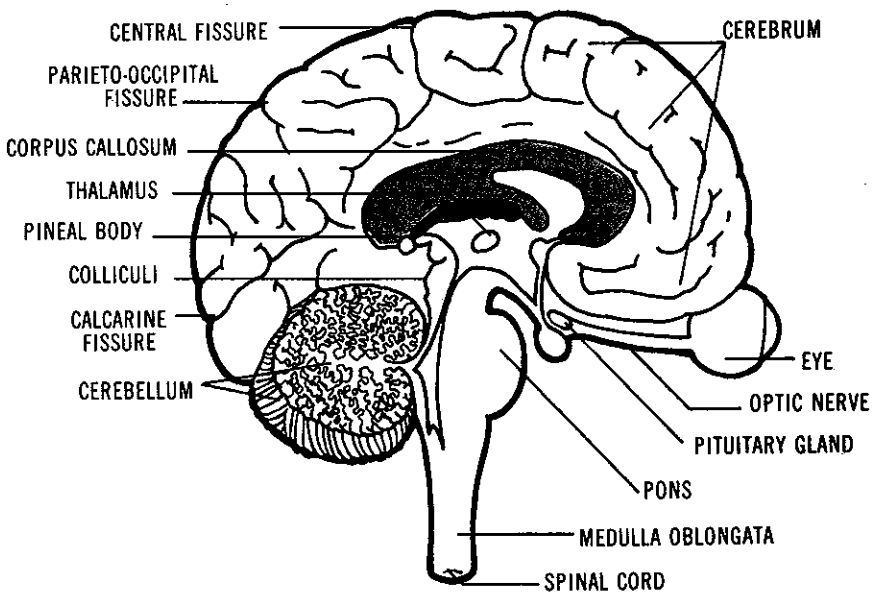

Fig. 1–27. Brain, midsection, lateral view (diagrammatic).

Another way to describe the nervous system is by *function*. Again there are two divisions: (1) the *voluntary* (cerebrospinal) system, which for the most part sets up conscious, deliberate bodily actions under the control of the will—plus reflex actions which may or may not be conscious; and (2) the *involuntary* (autonomic) system which is automatic and partly independent of the rest of the nervous system. The autonomic nervous system is subdivided into the *sympathetic* and the *parasympathetic* nervous systems.

Central Nervous System

The central nervous system is composed of two interconnected structures: the *brain* which is enclosed within the skull and protected by three membranes of connective tissue called *meninges;* and the *spinal cord* housed within a semiflexible bony column of vertebrae and composed of nerve cells that transmit impulses to and from the brain. From the brain 12 pairs of nerve trunks go out to various parts of the head and neck, and one pair goes down to the chest and the upper part of the abdominal cavity. From the spinal cord 31 pairs of nerve trunks go out to the neck, trunk, and limbs.

Brain

The brain which is the headquarters of the human nervous system is probably the most highly specialized organ in the body. It is critical to the functioning of the central and peripheral nerve networks. It weighs about three pounds in the average adult, is richly supplied with blood vessels, and requires considerable oxygen to perform effectively.

The brain has two main subdivisions: the *cerebrum* (large brain) which occupies nearly all of the cranial cavity and the *cerebellum* (small brain). The cerebrum is divided into two hemispheres by a deep cleft. The outer surface of the cerebrum, about one-eighth inch thick, is composed mainly of cell bodies of nerve cells, called "gray matter" or the *cerebral cortex*. The inner mass of cerebral tissue or "white matter" has interconnecting nerve fibers intermixed with small sections of "gray matter" that form special *ganglia* or control centers of nerve cells. These ganglia integrate and moderate the activities of nerve cells in the cortex. The surface of the brain is thrown into folds called convolutions that are separated from each other by grooves or fissures. These infoldings increase greatly the surface of the cortex.

Certain sections of the cerebrum are localized to control specific body functions as sensation, thought, and associative memory which allows us to store, recall, and make use of past experiences. Also, it initiates and manages those motions which are said to be "under the control of the will." The sight center of the brain is located in the back part called the *occipital lobe*. The *temporal lobe* at the side of the head deals with smell and hearing. The sensory and motor centers are separated by a transverse fissure at the middle of the top of the head. Centers of touch, taste, smell, and speech, among others have been recognized. An injury to any one center interferes with the specific function that it controls.

The *cerebellum* is located at the back of the cranium and below the cerebrum. Its main function is to coordinate muscular activity. Also it maintains balance in association with impulses from the eyes and the semicircular canals of the inner ears. Although the cerebellum cannot initiate a muscular contraction, it can hold muscles in a state of partial contraction which keeps a person from collapsing. It helps to coordinate the several muscular movements necessary to catch a ball.

Two smaller subdivisions of the brain that are vital to life are the *pons* and the *medulla oblongata.* The pons acts as a bridge that connects the cerebrum, cerebellum, and the medulla oblongata. The medulla oblongata protrudes from the skull slightly where it joins the spinal cord. It controls the activity of the internal organs, as the rate of respiration, heart action, muscular action of the walls of the digestive organs, and glandular secretions, among other activities.

Beneath the cerebral hemispheres of the forebrain are the *thalamus, hypothalamus,* and *pituitary* sections. The thalamus is a selective relay center for such impulses as those that relate to heat, cold, touch, and pain; also, it controls basic emotions as anger or fear. A lack of emotional control and marked changes in personality can be traced to dysfunctions of the thalamus. The hypothalamus, located next to the thalamus, has control centers that regulate the amount of fluid retained in the body, the appetite, the sex drive, the waking-sleeping cycle, and acts as a body temperature regulator. The *pituitary gland,* the master endocrine gland of the body, is attached to the hypothalamus and injury to either can upset many functions of the body's delicately balanced endocrine (glandular) system. (See Fig. 1–27.)

Within the brain are small cavities, the ventricles, which contain the *cerebrospinal fluid.* This fluid, produced by a plexus of blood vessels is a clear, watery solution similar to blood plasma. Circulating throughout the brain and spinal cord, it serves as a protective cushion and exchanges food and waste materials. The total quantity in the brain-spinal cord system is 100–150 ml, although up to several liters may be produced daily. It is constantly being produced and reabsorbed. Some diseases affect the reabsorption activity and pressure may build up within the system due to excess fluid. In the lower back between vertebrae, there is room for the insertion of a hypodermic needle to withdraw a sample of fluid for chemical examination. This spinal tap can furnish important diagnostic information on whether the volume of fluid and the pressure increased or decreased; on the fluid's composition, as content of protein or sugar; white blood cell count, and it can identify bacterial invaders.

Knowledge of nerve structure and function enables physicians to locate brain sections that are diseased. It is known that nerves from one side of the body eventually connect with the opposite side of the brain. Thus, a person whose left arm is paralyzed after a stroke is known to have suffered damage to the right side of the brain.

Spinal Cord

The spinal cord is a soft column of nerve tissue that is continuous with the lower part of the brain (*medulla oblongata*) and is enclosed in the bony vertebral column. Thirty-one pairs of spinal nerves branch from the spinal cord and are named generally for the vertebrae through which they emerge. These nerves are large trunks similar to telephone cables because they house many nerve fibers. Some fibers carry impulses into the spinal cord; others carry impulses away from it. Nerve impulses travel in one direction only along these fibers.

Spinal nerves at different levels of the cord regulate activities of various parts of the body. Eight pairs of *cervical nerves* activate muscles, bones, joints, and skin areas of the neck, shoulders, outer arm areas, wrists and hands. The next 12 pairs known as *thoracic nerves* act on parts of the trunk of the body from the shoulder level to a line about two inches below the navel; also they innervate the inner surfaces of the arm. Then come five pairs of *lumbar nerves* that emerge between lumbar vertebrae; five pairs of *sacral nerves* that emerge at the base of the spine; and one pair of *coccygeal nerves* that pass out between the sacrum and the coccyx bones. These last eleven pairs service the pelvic region of the trunk, the buttocks regions, and the legs. Also, branches of these lower spinal nerves merge to form two of the largest peripheral nerve trunks of the body: the *femoral nerve* that goes down the inner sides of the legs from groins to feet; and the *sciatic nerve* that extends along the back of the upper and lower legs to the feet.

Reflex Action

In addition to linking the brain with all the nerves of the body, the spinal cord is the center for *reflex actions*. A reflex action is the simplest form of nerve action. It is an automatic unconscious response wherein an impulse is relayed from one nerve to another without the brain being involved. The knee jerk is a good example of a simple reflex action. If the leg is allowed to swing freely and it is tapped just below the kneecap, the foot will jerk upward. The tap sets up an impulse in a sensory nerve from the lower leg. The impulse travels along a dendrite to the spinal cord where it contacts a central neuron to stimulate a motor nerve that activates leg muscles to cause a jerk. It is a split second automatic action that does not involve the brain.

When a hot object is touched, a similar reflex is experienced. The hand jerks away almost instantly. After the reflex is completed, the impulse continues to the brain and pain is registered. If the muscle response had been delayed until the pain impulse had reached the brain, and a motor impulse traveled back along the spinal cord from the cerebral motor area, there would have been a much greater burn injury. Such a reflex action not only can reduce the extent of the injury, it can be lifesaving. Other reflex actions are blinking the eyes, coughing, sneezing, and leaping when touched unexpectedly.

Peripheral Nervous System

The *peripheral nervous system* which carries both voluntary and involuntary impulses, is made up of (1) the 31 pairs of spinal nerves discussed previously that serve the spinal cord; (2) 12 pairs of cranial nerves that carry nerve messages to and from the brain; and (3) the autonomic (involuntary) nervous system.

The several divisions and subdivisions of the nervous system described herein represent an arbitrary procedure that depends upon whether we are considering its structure, function, or actions under the control of the will. No matter what specialized duties are involved, the various groups of nerves adapt to each other to form a coordinated unit.

The 12 pairs of cranial nerves innervate organs, muscles, and glands in the head. For example, the *optic nerve* innervates the eye; the *auditory nerve,* the ear; and the *olfactory nerve,* the organs of smell.

One cranial nerve—the *vagus nerve*—differs somewhat from the others in the head. It wanders out of the head to extend itself through the neck and chest to reach the abdomen. Along its path it connects with various organs to regulate rates of breathing and heartbeat, glandular secretion, and motility within the digestive tract. In this respect it acts as an *automatic nerve* to provide unbroken contact with involuntary (autonomic) control centers in the brain. This bypass of the vertebral column by the vagus nerve provides a supplemental pathway to allow the autonomic nervous system to continue its vital automatic functions unimpaired, if the spinal cord ever is injured severely or destroyed. Only when injury or disease affects the brain or brain stem will these vital involuntary body functions be disturbed.

Autonomic Nervous System

The *autonomic nervous system* is an auxiliary network of nerve tissue that regulates unconscious, involuntary body functions which must continue day and night, regardless of our desires. It excites into action the smooth muscle of the walls of blood vessels, the gastrointestinal tract, the lungs and heart, and stimulates internal secretions. The system governs automatic functions to which we normally pay no attention—including vital functions like breathing and the heartbeat.

The autonomic nerves belong to a group that is not directly under control of the brain, but usually work in harmony with those nerves that the brain controls.

The autonomic system is divided into the *sympathetic nervous system* and the *parasym-*

pathetic nervous system. Both systems act in delicate balance.

Sympathetic Nervous System

Sympathetic nerve trunks lie on both sides of the vertebral column, connect with nerve cells in the spinal cord, and extend motor fibers to the various organs that they control in the chest and the abdomen. Also, other motor fibers do not extend directly to the organs that they control; instead they unite or come together into groups of nerve cells or *ganglia* that act as interconnected control centers in the connective tissue that lines the chest and abdomen outside the spinal column on both sides. Special nerve cells in these ganglia send out fibers to form dense networks of nerves *(plexuses)* near the organs they control. The largest of these sympathetic ganglia is the *solar plexus,* located just below the diaphragm. Another is near the heart, a third is in the neck, and a fourth in the lower abdomen surrounds the testicles. The latter plexus of nerves accounts for the extreme sensitivity of the area and the excessive pain that results when struck by a blow.

The sympathetic nervous system helps to regulate heart action, arterial blood supply, secretions of ductless glands, smooth muscle action in stomach and intestine, plus action of other internal organs. An important function of the system is to increase body activity to enable it to meet danger. When challenged to meet stress, body processes are stepped up by discharge of stimulating secretions at nerve junctions. These secretions, plus adrenalin shot into the bloodstream, produce faster muscular action than could be gotten by hormonal releases from various glands. Heart and lung action increases, extra glucose is released from the liver for energy, and the body is prepared for a super effort.

Parasympathetic Nervous System

Ganglia of the *parasympathetic nervous system* are in the midportion of the brain, the medulla oblongata, and the sacral region of the spinal cord. This system opposes the sympathetic system. It prevents body processes from increasing to extremes. Secretions are discharged to slow the heartbeat, decrease lung action, and return body processes to normal after the threat of danger has been met.

Table 1–7

FUNCTIONS OF THE AUTONOMIC NERVOUS SYSTEM

Sympathetic	Parasympathetic
1. Dilates pupils.	1. Contracts pupils.
2. Lessens tonus of ciliary muscles so that the eyes may accommodate to see distant objects.	2. Contracts ciliary muscles so that the eyes may accommodate to see objects near at hand.
3. Dilates bronchi.	3. Constricts bronchi.
4. Quickens and strengthens the action of the heart.	4. Slows the action of the heart.
5. Contracts blood vessels of the skin and viscera so that more blood goes to the skeletal and cardiac muscles where it is needed for "fight or flight."	5. Dilates blood vessels (except cardiac).
6. Relaxes gastrointestinal tract and bladder.	6. Increases contractions of gastrointestinal tract and muscle tone of the bladder.
7. Decreases secretions of gastrointestinal glands.	7. Increases secretions of gastrointestinal glands.
8. Increases secretion of sweat glands.	8. No action on sweat glands.
9. Causes contraction of sphincters to prevent emtying of bowels or bladder.	9. Relaxes sphincters so that waste matter can be excreted.

The principal nerve of this system is the *vagus nerve,* which has been discussed previously under the peripheral nervous system. Through surgery, impulses from the vagus nerve can be diminished to lessen excess acid secretions in the stomach of a peptic ulcer patient.

Sympathetic vs Parasympathetic Systems

The sympathetic nervous system is concerned with making rapid adjustments to meet emergencies. The parasympathetic system deals mainly with digestion and the repair of wear and tear to the body.

The opposing functions of the two systems tend to keep the body in delicate balance. For example, in times of stress or danger it is more important that the heart pump extra blood to leg muscles to have us move away quickly from danger than for blood to go to digestive organs to act on food. Sympathetic nerve impulses speed the heart and slow digestion; parasympathetic impulses oppose these. The one system constricts blood vessels, the other dilates. The parasympathetic system acts more slowly than the sympathetic system's split-second response to danger. When there is no longer a need for "flight or fight," the former system forces a gradual slowdown of heart, lungs, and other organs for a return to normal functioning of body processes.

ENDOCRINE SYSTEM

Endocrine (or *ductless*) *glands* are the body's regulators. Secretions (*hormones*) of the glands are carried by the bloodstream to all parts of the body, affecting physical strength, mental ability, build, stature, reproduction, hair growth, voice pitch, and behavior. How people think, act, and feel depends largely on these minute secretions from the endocrine glands.

Endocrine glands, having no ducts, discharge their secretions (hormones) directly into the bloodstream. Each endocrine gland produces one or more hormones, which are chemical substances that have a specific effect on the activity of certain organs. Good health depends on a well-balanced output of hormones. Endocrine imbalance yields profound changes in growth and serious changes in mental, emotional, physical, and sexual behavior.

Some endocrine glands (see Fig. 1–28) and their functions follow:

- The *thyroid* gland in the neck produces thyroxin, a catalyst for oxidative (oxygen-using) processes in tissue metabolism.
- The *parathyroid* glands, near the thyroid, produce parathormone, necessary for the metabolism of calcium and phosphorus in bones.
- The *adrenal* glands atop the kidneys produce hormones that postpone muscular fatigue, in-

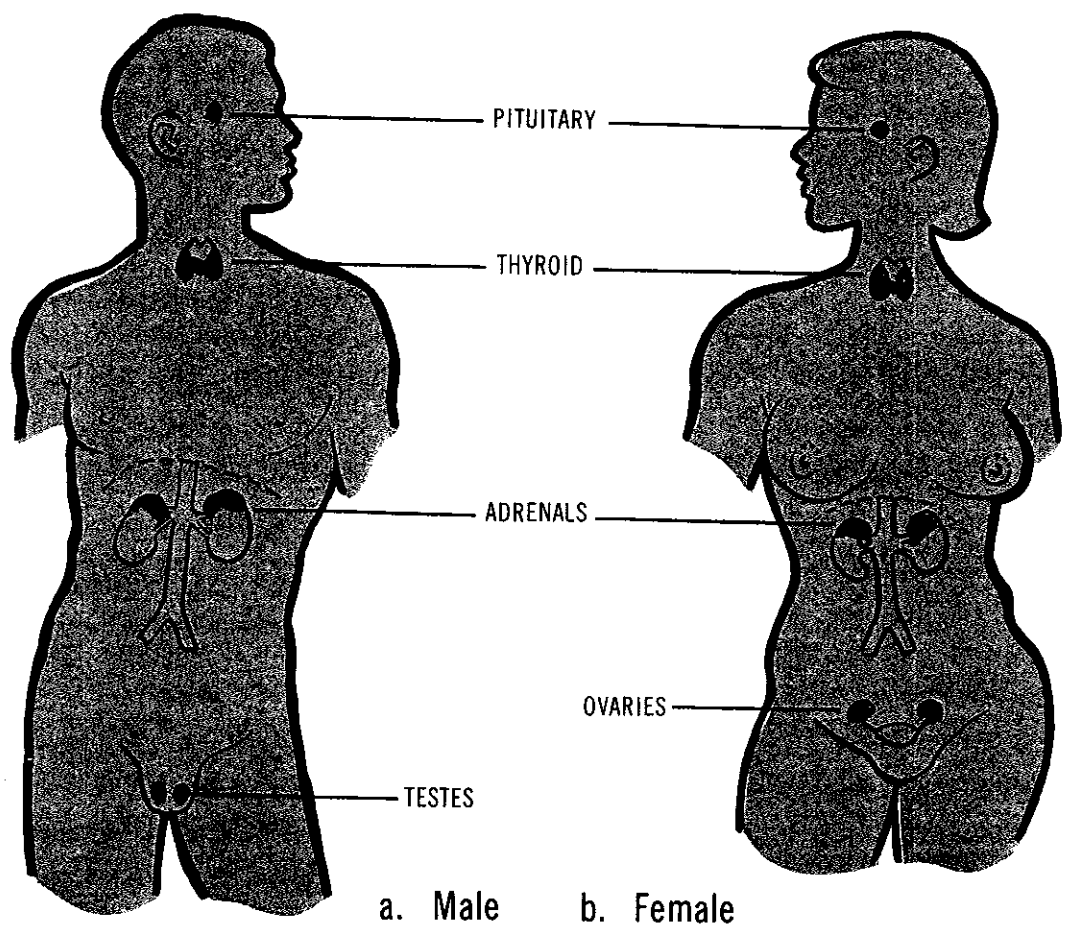

Fig. 1–28. Some endocrine glands.

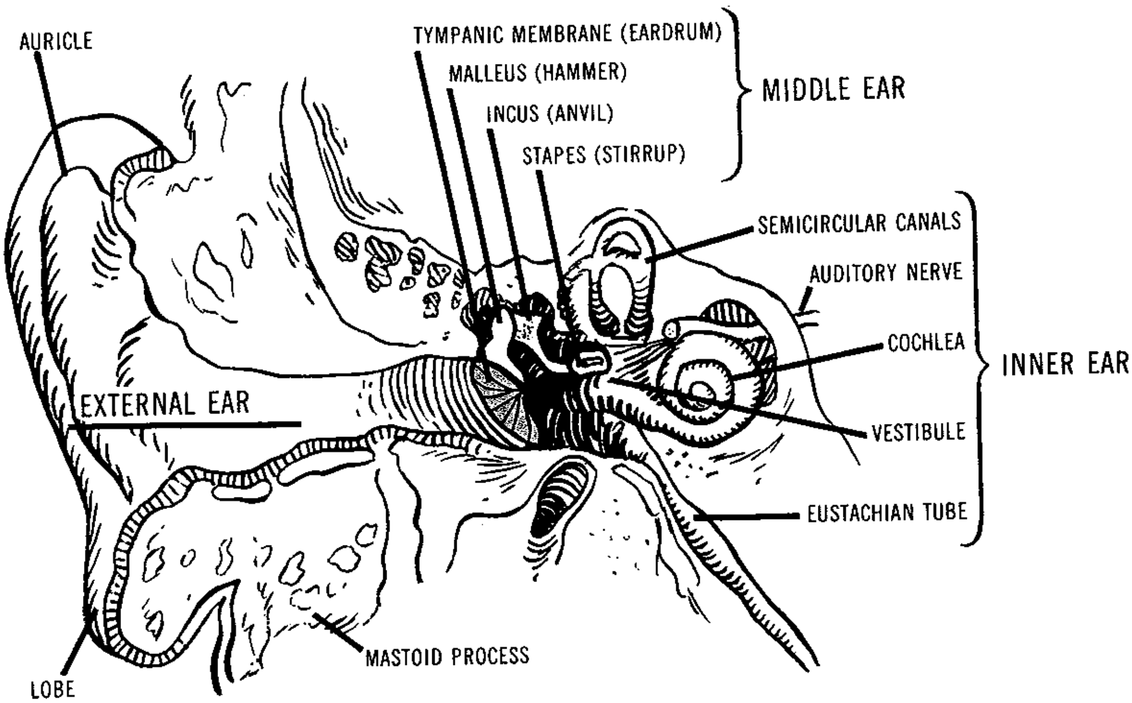

Fig. 1–29. Ear, right, diagrammatic.

crease the storing of glycogen (a sugar), control kidney function, and regulate the metabolism of salt and water.

- The *gonads* (ovaries and testes) produce the hormones governing reproduction and sex characteristics.
- The *islets of Langerhans* in the pancreas make insulin for sugar metabolism.
- The *pituitary* gland at the base of the brain behind the nose, is the "master gland" because its various hormones regulate growth, the thyroid and parathyroid glands, pancreas, gonads, metabolism of fatty acids and some basic proteins, blood sugar reactions, and urinary excretion.

EARS

The ear is concerned with the functions of hearing and equilibrium. There are three divisions of the ear: the *outer ear, middle ear,* and *inner ear.* (See Fig. 1–29.)

The outer ear is comprised of the auricle *(pinna)*, a skin-covered cartilaginous framework which projects from the head and the *external auditory canal.* This canal, lined with hairs and glands that secrete earwax *(cerumen)*, is S-shaped, about one inch long and extends to the middle ear.

The eardrum (*tympanic membrane* or *tympanum*) separates the external auditory canal from the middle ear. In the middle ear, three tiny movable bones (the *ossicles*) modify and conduct sound vibrations from the eardrum to the inner ear.

The eardrum and the ossicles are so delicate that violent vibrations of the air, like those caused by the explosion of a bomb or the firing of a heavy gun, may injure them. The three ossicles of each ear are called *malleus, incus,* and *stapes,* and in the order named, resemble a miniature hammer, anvil, and stirrup.

Air passes into or out of the middle ear through the *eustachian tube,* which leads to the upper part of the throat. The eustachian tube allows air pressure in the middle ear to equal that of air entering the external ear canal. A nose or throat infection can spread to the middle ear by way of the eustachian tube. Blowing the nose may force infected material into the middle ear. An infection of the middle ear may abscess (form pus), and running ears may result. Sometimes infection may extend from the middle ear to the *mastoid cells* in the temporal bone and cause mastoiditis.

Vibrations that are carried to the inner ear by the external canal, the eardrum, and the ossicles are converted into nerve impulses and transmitted to the brain by the auditory nerve. The inner ear consists of the *osseous* (bony) labyrinth and the *membranous* labyrinth. The osseous labyrinth is composed of a series of cavities: the vestibule, three *semicircular canals*, and the *cochlea* (snail shell). The membranous labyrinth is located within the osseous labyrinth and has the same general shape. The sense of hearing is transmitted to the auditory nerve through the cochlea. The semicircular canals are concerned with equilibrium. They are filled with fluid and any movement of the head results in a corresponding movement of the fluid in the three canals. The movement of the fluid generates nerve impulses, which cause a person to make adjustments in position to maintain balance. Motion of an airplane or of a ship can produce dizziness and nausea. This *motion sickness* may be called "sea sickness," "air sickness," or "bus sickness," depending upon the type of vehicle in which the person is riding when he experiences the symptoms.

EYES

The eye is a sphere approximately one inch in diameter formed by a tough outer coat called the *sclera* and the clear front portion known as the *cornea.* There are six muscles attached to the sclera which work in various combinations to move the eye. The ocular movements are very precise and rapid; primarily because there is more brain tissue devoted to controlling eye movements than to any other single motor function.

The cornea is the window through which light enters the eye. There are no blood vessels in the normal cornea, and it is extremely sensitive and especially susceptible to injury or infection. If scarring occurs from injury, the cornea loses its transparency at the site of the scar, which may markedly impair vision. The cornea has an extremely high concentration of nerve fibers which make it extremely sensitive to the slightest insult. A superficial scratch, abrasion, or the smallest foreign body can cause extreme pain with reflex tearing and redness (inflammation) of the eye.

The back surface of the eyelids and the exposed portion of the white part of the eye (sclera) are lined with a paper-thin covering called the *conjunctiva;* it does not cover the cornea. The conjunctiva may become infected and produce a red eye with a variable amount of pus, mucus, or water discharge. This infection is called conjunctivitis.

The internal portions of the eye are the *anterior chamber, iris, lens, vitreous body,* and *retina.* (See Fig. 1–30.) The anterior chamber, a space filled with watery fluid lies between the cornea and the colored portion of the eye (iris). The *iris* is a pigmented muscular structure which opens and closes the pupil to allow more or less light to enter the eye, depending on the level of illumination. This works much the same as the iris diaphragm on a camera which controls the amount of light that enters the camera.

Just behind the iris is a structure known as the *lens,* which can change shape to focus light rays on the back of the eye. When the lens becomes cloudy, it is called a *cataract.* In middle age the lens usually becomes somewhat less flexible, making it necessary to get reading glasses or bifocals. Behind the lens is the *vitreous body,* a cavity filled with a clear jelly known as the *vitreous humor.*

The innermost layer of the eye is the *retina* with specialized nerve cells, which are sensitive to light and color. The retina acts much the same as the film in a camera, except the retina receives the light rays and converts them into nerve impulses which are transmitted to the

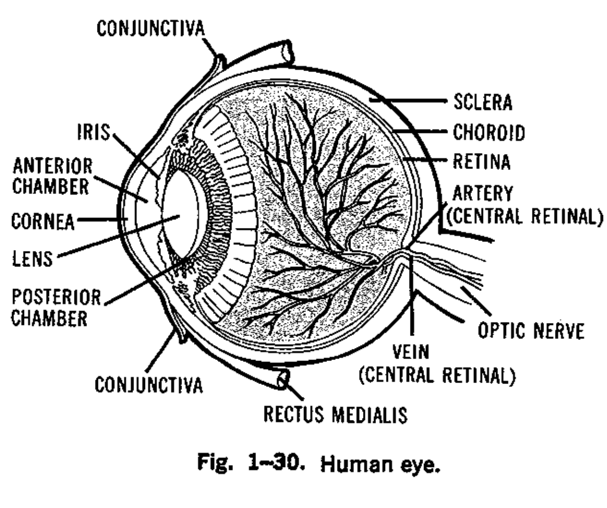

Fig. 1–30. Human eye.

brain by the *optic nerve.* In the brain the nerve impulses are interpreted as sight.

A tear gland (*lacrimal gland*), located under the outer part of the upper lid, is constantly producing tears to keep the eye moist and lubricated so the eyeball can glide smoothly under the eyelid. When the eye is irritated, tear production is increased to help wash away the irritant.

The eye is protected and cleansed by the *eyelids.* They spread the tears over the front of the eye and tend to wipe away dust and other foreign particles. Along the edges of the eyelids are openings of many small oil glands which help prevent too rapid evaporation of tears. The lashes and eyebrows tend to prevent foreign material from entering the eye. At the inner corner of each upper and lower lid is a small pinpoint opening called the *punctum.* Through this opening the tears drain into a small tube which in turn empties into a passage known as the nasolacrimal duct. This duct empties the tears into the nose.